Fall 1973

SALIVARY INFLUENCES OF FLUID PREFERENCES AND AVERSIONS IN THE ALBINO RAT

WILLIAM BRADFORD LAWSON

INFORMATION TO USERS

This dissertation was produced from a microfilm copy of the original document. While the most advanced technological means to photograph and reproduce this document have been used, the quality is heavily dependent upon the quality of the original submitted.

The following explanation of techniques is provided to help you understand markings or patterns which may appear on this reproduction.

1. The sign or "target" for pages apparently lacking from the document photographed is "Missing Page(s)". If it was possible to obtain the missing page(s) or section, they are spliced into the film along with adjacent pages. This may have necessitated cutting thru an image and duplicating adjacent pages to insure you complete continuity.

2. When an image on the film is obliterated with a large round black mark, it is an indication that the photographer suspected that the copy may have moved during exposure and thus cause a blurred image. You will find a good image of the page in the adjacent frame.

3. When a map, drawing or chart, etc., was part of the material being photographed the photographer followed a definite method in "sectioning" the material. It is customary to begin photoing at the upper left hand corner of a large sheet and to continue photoing from left to right in equal sections with a small overlap. If necessary, sectioning is continued again — beginning below the first row and continuing on until complete.

4. The majority of users indicate that the textual content is of greatest value, however, a somewhat higher quality reproduction could be made from "photographs" if essential to the understanding of the dissertation. Silver prints of "photographs" may be ordered at additional charge by writing the Order Department, giving the catalog number, title, author and specific pages you wish reproduced.

University Microfilms

300 North Zeeb Road
Ann Arbor, Michigan 48106

A Xerox Education Company

SALIVARY INFLUENCES ON FLUID PREFERENCES AND AVERSIONS IN THE ALBINO RAT

by

WILLIAM B. LAWSON

B.S., Howard University, 1966

M.A., University of Virginia, 1969

A DISSERTATION

Submitted to the University of New Hampshire

In Partial Fulfillment of

The Requirements for the Degree of

Doctor of Philosophy

Graduate School

Department of Psychology

November, 1972

This thesis has been examined and approved.

Earl C. Heaptom

Gregory J. Bertsch

Philip J. Sawyer

Edward N. Francq

Date Nov-4, 1972

ACKNOWLEDGEMENTS

This research was supported by Grant MH 48 495 from the Mental Health Division of the National Institute of Health.

The author is greatly indebted to Dr. Earl C. Hagstrom for his guidance, constructive criticism, and above all, his patience throughout the development of this thesis.

The author wishes to express his appreciation to Drs. James Davis and Gregory Bertsch for their helpful suggestions and their critical but quite constructive comments, and to Drs. Phillip Sawyer and Edward Francq of the Department of Zoology for their helpful guidance.

The author wishes to acknowledge the helpfulness of Dr. William P. Paré in providing needed technical information.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Figure

ABSTRACT

SALIVARY INFLUENCES ON FLUID PREFERENCES AND AVERSIONS IN THE ALBINO RAT

by

WILLIAM B. LAWSON

Research into the bases of ingestion have commonly employed methods of fluid preferences and aversions. Specific hunger research has indicated that such preferences may change with need state, especially in the case of salt appetite. Research involving the mechanisms underlying salt appetite has generated interest in the fluid environment of the mouth as a significant factor underlying changes in preference with bodily need.

Human and animal research has shown that fluid preference and other taste dependent behavior may vary with changes in the mouth's fluid environment and animal research has shown that surgical elimination of salivary flow produces changes in fluid preferences and aversions. The following experiments were undertaken to determine the bases of the changes in fluid preferences seen when the mouth's fluid environment is varied.

Experiments I-V. Previous research has shown that animals surgically desalivated developed a prandial drinking pattern in which small morsels of food were followed by small drafts of water in order to ingest dry food with a dry mouth. These animals also showed a loss of NaCl preference, but only when offered dry food. Apparently the close occurrence of eating and drinking during prandial drinking resulted in

the food taste masking the salt taste. These experiments examined this masking effect of solutions other than NaCl.

Rats were surgically desalivated by ligating the ducts of the major salivary glands and were given two-bottle preference tests. Desalivated rats in comparison to intact controls showed less quinine aversion and a decrease in preference over a range of saccharin and sucrose solutions. This preference shift was seen only in the presence of dry food. In the absence of food, aversion to quinine as well as preferences for saccharin and sucrose did not differ from controls.

The preference shift seen with desalivation therefore depends on the presence of dry food and apparently results from a nonspecific taste masking effect due to prandial drinking.

The desalivates also differed from controls in total intake. In Experiment I, with quinine (14 days postoperative), desalivates showed the high fluid intake associated with prandial drinking when food was present. This effect was not seen in a significant degree with test solutions of saccharin and sucrose (40 days postoperative). Without food, desalivates drank significantly less fluid even when the lower body weight of the desalivates was taken into account.

Experiment VI. If the preference shift seen in desalivates was a result of prandial drinking rather than a direct effect of the absence of saliva, then a similar shift in preference should occur if intact rats were to become prandial drinkers. Prandial drinking was induced in intact rats by an operant schedule in which food pellet delivery was contingent on drinking.

A prandial drinking pattern similar to that seen with desalivation was induced. Quinine aversion was significantly reduced and returned to precontingency levels with termination of the schedule.

Experiment VII. Desalivated rats had been reported to show a preference enhancement for NaCl, followed by the preference loss. Presumably this enhancement represented a direct effect of elimination of salivary flow and the preference loss resulted from the prandial drinking pattern. The development of prandial drinking depends on the texture of the animal's diet. Animals were presented diets differing in texture and desalivated in order to separate the factors underlying NaCl preference.

A regular diet of chow pellets produced a preference loss within 4 days, about the time that prandial drinking developed. Dry powder which delayed prandial drinking also delayed the preference loss. A wet mash diet, which did not produce prandial drinking, also did not produce a preference loss. No evidence was seen for a preference enhancement.

Experiment VIII. The fluid environment of the mouth was controlled in intact rats and desalivates by direct infusion of the mouth through an oral fistula. With water and NaCl infused, controls showed a transient preference loss. Desalivates showed an enhancement of their initially low preference to the level of the controls with water infused. There was evidence that prandial drinking was disrupted. With NaCl infused, desalivates showed either a low preference with evidence of prandial drinking or a return of preference and loss of prandial drinking.

The major effect seen with varying the fluid environment of the mouth in these experiments was a preference shift that resulted from the prandial drinking pattern that desalivated animals develop. When prandial drinking was controlled or the fluid environment directly manipulated, only transient changes in preference were seen.

INTRODUCTION

Methods of fluid preferences and aversions are today commonly used in research involving the factors underlying ingestion. Such methods were first used to demonstrate specific hungers as a basis of self regulatory functions in rats (Richter, 1942-43; Young, 1949). Today the use of fluid preferences and aversions has become a common model for the investigation of taste and ingestion.

The most commonly used methods are the two bottle and the single bottle techniques. In the two bottle situation, choice is given between the test solution and water. In the single bottle situation, the test solution is presented alone and comparisons may be made with the solution at other concentrations or a water baseline.

As a result of these methods, two types of ingestive behaviors may be distinguished. One such behavior is demonstrated when low concentrations of sodium chloride, saccharin, or a number of sugar solutions are ingested. Such solutions, when serving as the test solutions, will be ingested in greater quantities than water, or in the single bottle situation, greater than a water baseline. This type of ingestive behavior is called a preference, and these solutions are referred to as preferred solutions. Carpenter (1956) gave examples of such preferences in different species. The other type of behavior is called an aversion. Such behavior is elicited by solutions which are rejected, such as those composed of quinine compounds. Such solutions are rejected in favor of water as soon as they are tasted (Wendell, 1936), or, in the single bottle situation, ingested less than a water baseline.

As the concentration of a preferred solution increases, the preference for that solution increases and reaches a peak. Preference then decreases until intake of the solution may be less than that of water, or a water baseline. This function, with an ascending preference limb and a descending aversion limb across concentration, is called a preference-aversion function. Its generality across a variety of solutions and species makes it a useful model in the investigation of factors underlying ingestion. Richter and Campbell (1940) presented the functions for several sugars. Though the absolute values of intake at various concentrations differed, the general function was present across sugars. While species may differ in taste preferences to various solutions (Carpenter, 1956), if a preference is expressed initially, a typical preference-aversion function results. Stellar (1967) notes the similarity in the shape of the function of glucose in man, rat, and blowfly.

One adaptive feature of preference behavior is a hunger for specific nutrients or foods, with body deprivation of that nutrient (Richter, 1942-43). Interest in such specific hungers, especially in the case of salt appetite, led to an interest in the influence of salivary flow on preference behaviors. With sodium depletion either through adrenalectomy (Richter, 1936; Richer and Eckert, 1938) or dietary deprivation (Nachman and Pfaffmann, 1963), rats show an increase in salt preference. Humans may show a lower salt taste threshold as well as a salt craving (Henkins and Solomon, 1962; Henkins, Gill, and Bartter, 1963; Yensen, 1959; deWardener and Herxheimer, 1957). The invariance of the receptor response when measured electrophysiologically

in rats (Pfaffmann and Bare, 1949; Nachman and Pfaffman, 1963) would seem to exclude a taste mechanism as a basis for this change. Yet the importance of a taste mechanism is demonstrated by the finding that denervation of the taste buds prevents the expression of the salt preference necessary for the survival of the adrenalectomized rat (Richter, 1939). Also if NaCl is tasted but water is intubed, the preference increase still occurs (Mook, 1969). Finally the intake of salt concentrations too low to be of physiological benefit are also increased (Bare, 1949).

The preference effects may result from changes in salivary electrolytes. Specifically changes may have occurred in the sodium concentration, or the sodium/potassium ratio, these being the major ions in saliva. Salivary sodium level does drop under salt deprivation, as well as the Na/K ratio (Blair-West, Coghlen, Denton and Wright, 1967; McCance, 1938; Thaysen, 1956).

Pfaffmann and his students presented direct evidence for the role of saliva in salt taste. The concentration of an adapting solution on the tongue determined salt taste thresholds in humans, with the threshold concentration lying slightly above that of the adapting solution (McBurney and Pfaffmann, 1963). The taste of a salt solution also depends on the concentration of an adapting solution (Bartoshuk, McBurney and Pfaffmann, 1964). Solutions below the concentration of the adapting solution taste sour or bitter while those above threshold taste salty or sweet. Note that the taste experience may be changed without changing the test solution simply by changing the fluid environment of the tongue. Finally, the resting level of the electrophysiological

response for the chorda tympani nerve in the rat varies with the concentration of a previously adapting solution (Pfaffmann and Powers, 1964). Salt depletion therefore may influence preference and detection by changing the salivation concentrations and subsequently the adaptation level of the tongue.

Pfaffmann (1963, 1967) doubted changes in salivary electrolytes alone accounted for changes in salt appetite. First, salt deficiency produces a preference for normally aversive salt solutions. Changes in salivary electrolytes however should increase sensitivity and therefore increase the aversive response. Second, the stimulus solution, after the first few laps, will flood the receptors and drown out any salivary effects.

That changes in salt appetite result from changes in salivary electrolytes is also inconsistent with empirical findings. There is no consistent relationship between salt taste thresholds and serum Na or the Na/K ratio in man (deWardener and Herxheimer, 1957; Henkins and Solomon, 1962; Henkins et al., 1963). Also the salt detection threshold in rats shows no change in sensitivity after salt deficiency (Carr, 1952; Harriman and MacLeod, 1953). Finally, the surgical elimination of salivary flow has little effect on the salt preference increase produced by salt deficiency in the rat (Vance, 1965).

Subsequent studies will show salivary flow may indeed mediate salt preference under other circumstances. There is direct evidence for saliva influencing taste in man. Cragg (1937) found a relationship between the pH of saliva and sour taste. Acid appeared more sour in

subjects whose saliva was more acid, and less sour to those subjects whose saliva was more basic.

Taste blindness to the bitter substance pheno-thio-carbamide (PTC) seems to be determined by salivary events (Cohen and Ogdon, 1949A). Furthermore, the ability to taste PTC in man depends on the presence of saliva (Salmon and Blakeslee, 1935). Subjects that are able to taste PTC (tasters), can do so only when PTC is dissolved in their own saliva (Cohen and Ogdon, 1949B). They cannot taste PTC when it is dissolved in the saliva of other tasters or of those that cannot taste PTC. Finally these same researchers found a loss in the ability to detect salt and saccharin when the tongue was dry.

The experimental elimination of the salivary flow has been found to change both fluid preferences and aversions in the albino rat. Some question remains as to how these changes occur.

Vance (1965) in a series of studies surgically reduced salivary flow in albino rats and produced changes in preference behavior as well as food and water intakes. Included were changes in the preference of a NaCl solution over water. Immediately after desalivation, preference and total intake increased dramatically, then fell below predesalivation levels. He concluded that these findings resulted from a direct effect of the absence of saliva on the taste receptors.

Kissileff (1967) desalivated rats by removal of salivary glands, in addition to the technique that Vance used of ligating the ducts. He also found a preference decrease. This decrease was interpreted as being the result of the eating and drinking pattern that desalivate rats demonstrate rather than as a direct effect of the reduction of salivary

flow on the taste receptors. Desalivate rats show an exaggerated prandial drinking pattern. They drink as they eat, alternating between bits of food and drafts of water, to alleviate the difficulty of eating dry food with a dry mouth (Epstein, Spector and Samman, 1964; Kissileff, 1969A, 1969B; Stricker, 1970). Kissileff found that saline preference returned when food was not present. He concluded that preference was disrupted by the prandial pattern and not the desalivation. Prandial drinking may prevent the expression of preference by causing the taste of the preferred solution to be "masked" because eating and drinking occur simultaneously.

An attempt was made to replicate these findings (Lawson, 1969), but with atropine-induced desalivation to control for any disparate results due to surgical technique. A slight increase was found with a subsequent decrease in preference. This was similar to Vance's finding, except for the less marked preference enhancement. In addition the decrease paralleled the development of prandial drinking. Another study was run in which prandial drinking was controlled by alternating days on which food was available with days on which food was absent. When food was present, preference was found to depend on the extent of prandial drinking, with the animals having strongest preference showing the poorest prandial drinking. On the days without food all animals not only maintained a preference, but showed a slight enhancement.

Summary

Methods for determining fluid preferences and aversions are commonly used in research concerning the bases of ingestion. Preferred

solutions generate a characteristic preference-aversion function with increasing concentration of the solution. Specific hunger research involving salt appetite has demonstrated that preference may change with need state. The data showing changes in preference with biological need states, as in the case of salt appetite, has implicated the fluid environment of the mouth as a factor that determines preference behavior. Salt preference does change with need state, but the response of taste receptors seems to be relatively invariant under such conditions. Salivary content, however, does change with bodily states and may modify the response of the taste receptors. Both human and animal taste research has demonstrated the importance of the fluid environment of the tongue. Specifically, in animal research, removal of the salivary flow results in changes in both fluid preferences and aversions.

Specific Problem

It can be inferred from the previously cited studies that two events affect NaCl preferences following desalivation. First, there is a dry mouth condition that leads to an increased NaCl preference. Second, there is a prandial drinking pattern that desalivate rats develop when ingesting dry food which also leads to a decrease in preference. While such factors provide a general conception of the role of salivary flow with NaCl preference, additional research is needed to determine if such a model will account for the variety of findings with several solutions reported by Vance (1965). In addition further investigation is required to elucidate the nature of the two probable factors that affect preference. Specifically, it is not known to what

extent food dependent effects can be generalized. Kissileff's (1967) and Lawson's (1969) work concerning the loss in preference involved only NaCl solution, which is associated with the salt taste. No one has examined the generality of this food dependent effect to determine if it will affect solutions associated with tastes other than salt. In fact this effect may be specific to NaCl. It could also account for the other preference changes that Vance (1965) reported. For example, Vance also found a loss in quinine aversion with desalivation that may have been a result of some sort of taste masking.

The loss in preference with desalivation may result from prandial drinking. The concurrent eating of dry food and drinking of the test solution may cause the food to mask the taste of the test solution. Such an explanation would account for the food dependence of the phenomenon, but there is no direct evidence that such masking can indeed occur.

Similarly, the enhancement in preference was assumed to result directly from the absence of saliva. However the only manipulation that has been made was the removal of saliva. In addition this phenomenon, when demonstrated, generally has been confounded by the presence of prandial drinking, which itself is associated with desalivation and the preference loss effect.

EXPERIMENTS

This dissertation reports a series of studies in which the problems of the effects of salivary flow of fluid preference were examined.

The first group of studies (Experiments I-V) determined if the masking effect of prandial drinking could account for the desalivates' changes in preference with fluids other than NaCl. In Experiment VI prandial drinking was induced without desalivation to determine if the food associated drinking, rather than desalivation, could account for the preference changes.

The next study (Experiment VII) investigated the influence of desalivation on preferences when the potentially confounding effects of prandial drinking were removed by substituting a diet that prevented the occurrence of prandial drinking.

The final experiment (Experiment VIII) examined the effects of oral infusion on desalivate rats to determine if the preference changes associated with such animals simply reflected the absence of the appropriate fluid environment on the tongue.

Experiment I

The Masking Effect and Preferences and Aversions in Desalivates

The preference loss for NaCl in desalivates depends on the presence of dry food, apparently because the food masks the salt taste (Kissileff, 1967; Lawson, 1969). Vance (1965) reported that desalivates showed less aversiveness to quinine over a number of concentrations.

Experiment I determined if the loss in quinine aversion can be accounted for by the masking hypothesis. Quinine aversion was determined with and without food. If the masking hypothesis is correct, then quinine in the absence of food should be as aversive to desalivates as to controls.

The response of desalivates to water might serve as a basis for an alternative hypothesis. Vance found that desalivates drink more water than intact animals in the presence of dry food, but far less when prandial drinking is unnecessary, that is, when food is absent or wet food is available. They also drink less in response to injections of the thirst inducing agents hypertonic saline and polyethylene glycol (Stricker and Wolf, 1969; Vance, 1965).

This reduced water intake may reflect an "aversion" to water by desalivates. Water would not be a neutral stimulus for these animals, but a mildly aversive fluid that (in a two-bottle test) may prevent quinine rejection from being expressed.

A measurement of quinine aversion with and without food would be one way to determine which of these positions is untenable. If the masking hypothesis is valid, then the desalivate group will not differ from the controls in quinine aversion when food is absent. If the water aversion hypothesis accounts for the decreased aversion, then the presence and absence of food may affect total intake but not the quinine/water ratio.

Procedure

The Ss in this and subsequent studies were adult female albino rats. In this study 14 rats with a mean weight of 254.2 grams were used.

Seven of these were randomly selected and desalivated by ligation of the major salivary ducts. The Ss were housed in wire mesh cages. They were presented with a choice between a .000%wt./vol. quinine hydrochloride solution and water in 100-ml. graduated cylinders (Nalgene) fitted with rubber stoppers and glass spouts. This quinine concentration was selected because it produced the largest difference between desalivates and controls in Vance's study (1965). The positions of the drinking tubes were alternated daily to control for position preference.

For 4 days food (Purina Chow Pellets) was freely available. Food was then removed and remained unavailable for 4 more days. Finally food was returned and was available for the final 4 days of the study. Comparisons were made between the desalivated animals and controls for both intake and percentage of quinine drunk.

Surgery

The rat has four pairs of salivary glands: the parotid, submaxillary, and major and minor sublinguals (Green, 1959). Desalivation was accomplished by bilateral ligation of the ducts of the parotids, submaxillaries, and major sublinguals. The minor sublinguals were left intact because they are virtually inaccessible without severe surgical trauma; their contribution to total saliva volume is negligible (Schneyer and Schneyer, 1959) and their extirpation does not produce any noticeable behavioral changes (Epstein et al., 1964).

A short incision along the midventral line exposed the submaxillary and major sublingual glands in their common sheath. The ducts of both types of glands were occluded as one, by double ligatures.

Bilateral incisions just behind and below the ear exposed the parotid ducts as they crossed the lateral aspect of the masseter muscle. The ducts were teased away from the ramus mandiburlaris marginalis, a sensory motor branch of the fifth cranial nerve serving the lower lip, which runs in close association with the duct. The duct was ligated above the point of separation and below including the nerve as well. All operations were performed under ether anesthesia.

Results

Observations of Eating and Drinking Behavior

After surgery, the desalivated animals had difficulty in chewing and lost weight. By the fifth postoperative day all animals had developed a prandial drinking pattern and regained part of the lost weight. This drinking pattern consists of an animal positioning itself next to a drinking spout, chewing for about five seconds, and drinking a few drafts while chewing. The alternation between chewing and drinking could be seen whenever these animals ate and would continue throughout eating.

The intact animals, on the other hand, would drink before or after a meal in a series of long drafts, but never in short bursts throughout a meal.

In addition, despite daily washing, the drinking spouts of the desalivates would accumulate a great deal of food deposits. Such an observation is not surprising considering the drinking pattern of these animals. Both the eating-drinking pattern and the tendency to accumulate food deposits in the drinking spouts persisted in these animals throughout the experiment.

Fluid Intake

Figure 1 Top shows the mean daily intake of desalivates and controls two weeks postoperatively. A two-way analysis of variance of the data, with desalivates X controls as one factor and the presence or absence of the food as the other, showed a significant interaction ($F = 6.01$, $df = 2.24$, $p < .01$) demonstrating that intake depended on both whether the animal was desalivated and the presence or absence of food. Analysis of simple effects and the Newman-Keuls post-hoc test yielded the following conclusions.

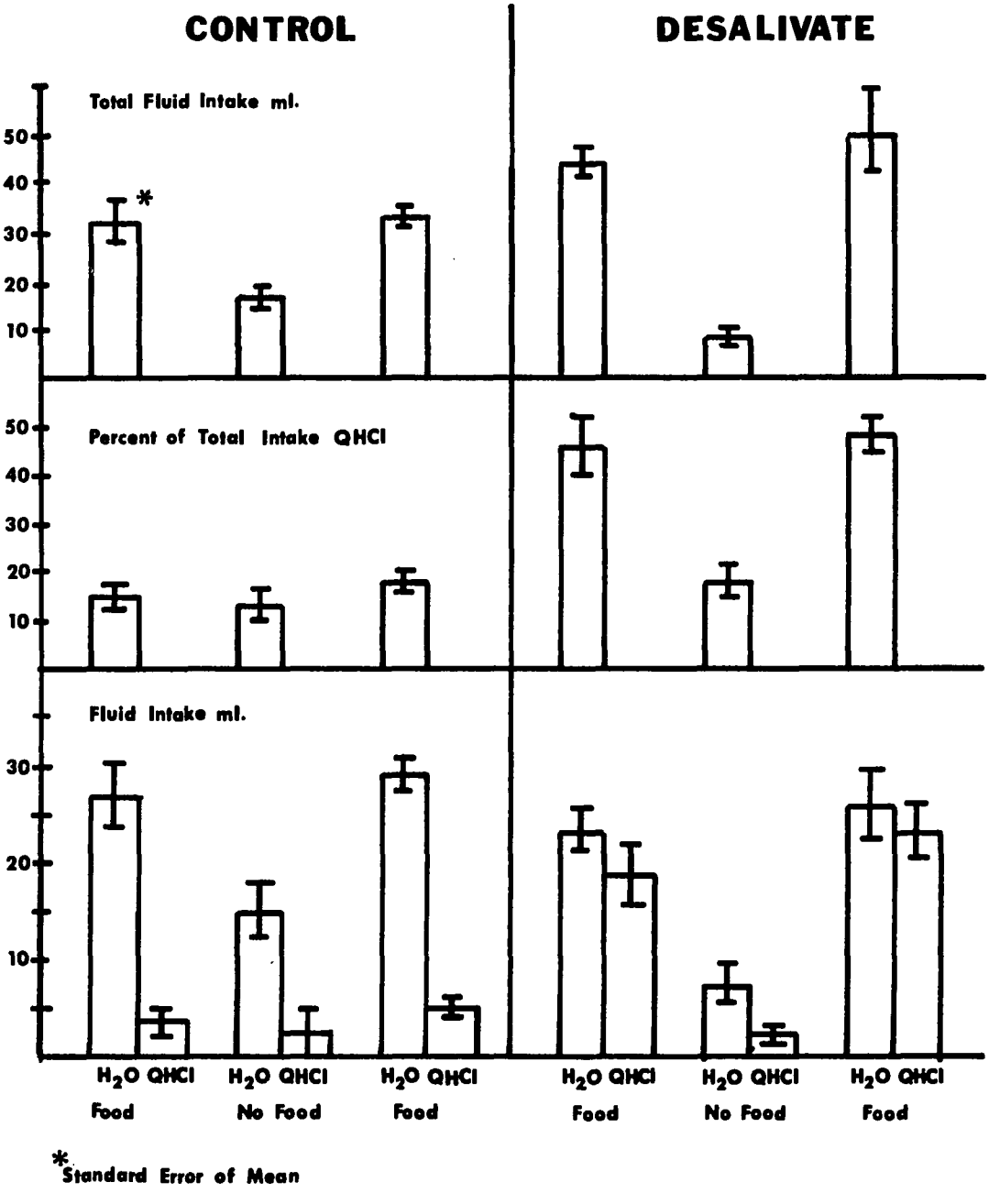
First, the presence and absence of food significantly influenced the intake of both the desalivates ($F = 37.5$, $df = 2/24$, $p < .01$) and the controls ($F = 6.9$, $df = 2/24$, $p < .01$). Both groups of animals drank more when food was present than when food was absent (all p's $< .01$) and intake did not differ significantly for either group between the two sessions in which food was present.

Desalivates drank significantly more than the controls when food was present ($F = 4.94$, $df = 1/36$, $p < .05$) for the first session, and ($F = 13.02$, $df = 1/36$, $p < .01$) for the second session. Yet mean intake of the desalivates fell below that of the controls when food was absent, although the difference did not attain signficance ($F = 2.54$, $p < .10$ but $> .05$).

Preference Behavior

A three-way analysis of variance design was employed to analyze the per cent of quinine intake. Desalivated vs. controls, food vs. no food on each of four test days were the factors. Since there was a cross-over in quinine aversion for desalivates vs. controls with no

Figure 1. Two-bottle preference tests in desalivate rats and control rats with .001% QHCl as the test solution in the presence and absence of dry food



*Standard Error of Mean

food, but not in the food sessions, test days may have been a factor. The triple interaction was not significant ($F < 1$), but the desalivation X food interaction was significant ($F = 19.47$, $df = 2/24$, $p < .01$) indicating that days was not a factor in the differences involving the other two variables. For this reason and especially since no other test day interactions were suggested, this factor was not considered in subsequent studies involving this section. The important point is that desalivation and the presence of food significantly interacted. Simple-simple main effects plus the Neuman-Keuls post-hoc test was used for further analysis.

Figure 1 Middle shows the per cent of total intake for quinine for desalivates and controls when food is present and when food is absent. In the presence of food, desalivates showed a marked impairment in quinine aversion. These animals drank a significantly greater proportion of quinine than the controls in the presence of food ($F = 95.1$, $df = 1/12$, $p < .01$). In fact the quinine solution made up nearly 50% of the total intake, while the controls showed a strong aversion, with quinine making up less than 20% of their intake.

In the absence of food the desalivates showed a substantial increase in quinine aversion. In fact the proportion of quinine ingested approached that of the controls ($F < 1$). In both instances a definite quinine aversion exists, with the proportion of quinine ingested falling to less than 20% of the total intake. When food was again made available the desalivates once again showed a loss in aversion with the desalivates ingesting a significantly larger proportion of quinine ($F = 103.15$, $df = 1/12$, $p < .01$). All changes reflect changes in the

quinine aversion of the desalivates. They, but not the controls, showed significant differences from food to nonfood sessions ($p < .01$ for the desalivates).

Using proportions as a measure of preference can be misleading especially with extreme differences in intake. For this reason, intake was also analyzed in a three-way design with desalivates vs. controls, food vs. no food, and quinine intake vs. water intake as the measures. Four day intake total were used as the dependent variable. The triple interaction was significant ($F = 6.92$, $df = 2/24$, $p < .01$). Simple-simple main effects were used to make the following statements of significance.

Figure 1 Bottom shows 4 day mean quinine and water intake for desalivates and controls with and without food. With food, desalivates drank far more quinine than the controls ($F = 28.70$, $df = 1/72$, $p < .01$). But more importantly, even if the intake differences are considered, note that quinine and water intake fell for the desalivates, but quinine intake showed a greater decline such that it was negligible. In fact quinine intake did not differ significantly between desalivates and controls ($F < 1$). When food was returned, the groups again differed significantly in quinine intake, with desalivates drinking far more than the controls ($F = 51.16$, $df = 1.72$, $p < .01$).

Note especially that though quinine and water intake was higher in both groups with food present, quinine intake showed a proportionally greater increase in comparison to water intake in the desalivates. While quinine and water intake differed significantly in desalivates in the first session with food present ($F = 4.58$, $df = 1/36$, $p < .05$),

in the second session with food present desalivates showed even less discrimination. Then there was no significant difference in quinine and water intake ($F = 2.02$, $df = 1/36$, $p > .10$).

Discussion

Total Intake

The findings of changes in fluid intake in desalivates over intact rats when food was removed and when food was returned demonstrated the extent to which dry food exerted control over intake in desalivated rats. Because of the difficulty of ingesting dry food with a dry mouth these animals drank excessive amounts of water in the presence of dry food. Drinking was acting as an operant for eating rather than a way to regulate water balance (Kissileff, 1970A,B). The excessive drinking has been consistently reported by observers of prandial drinking (Epstein, et al., 1964; Kissileff, 1969A; Stricker, 1970; Vance, 1965). Note also that more was drunk when food was returned than in the first test period. Apparently the animals ate more after their fast and this in turn elevated intake, again demonstrating the control of water intake by food intake.

Preference Behavior

The demonstration of an aversion to quinine with food absent weakens the hypothesis that a loss in quinine aversion represents some sort of permanent modification in the receptor response, as Vance (1965) and Halpern (1967) suggested. If, as Halpern suggested, there is a modification of receptor cell population and functional characteristics after desalivation, responsiveness should not be just a function of

testing condition. The same is true if there is a generalized decrease in sensitivity from receptor cell damage as a result of desalivation. In addition, the water aversion hypothesis is also untenable. Again, the lack of responsiveness to quinine should be maintained in the absence of food if this hypothesis is valid.

These findings extend Kissileff's (1967) observation with salt preference. Rather than being specific to NaCl, this preference loss effect can be extended to another substance associated with a different taste quality. The influence of food on salt preference could have been accounted for by the adapting qualities of the salt in the food, as Kissileff has suggested (personal communication). These findings invalidate such a suggestion. The loss in quinine aversion demonstrated that the presence of dry food produces a general loss in taste responsiveness.

Experiment II

In this experiment, the effect of desalivation on the preference for a nonnutritive but sweet solution was examined with dry food available, to determine if the preference loss effect can occur with a sweet solution. Pilot work demonstrated that such a loss does occur.

Method

Subjects were six desalivates and six controls from Experiment I, now 40 days postoperative. While housed in steel mesh cages, the animals were presented with increasing concentrations of sodium saccharin in two-bottle tests with saccharin and water. Each concentration was presented for 48 hours, and position of the saccharin and

water switched every 24 hours. The concentrations were .003%, .01%, .03%, .1%, and .3%. No concentrations in the aversive range were used to prevent generalizations to the subsequent experiment.

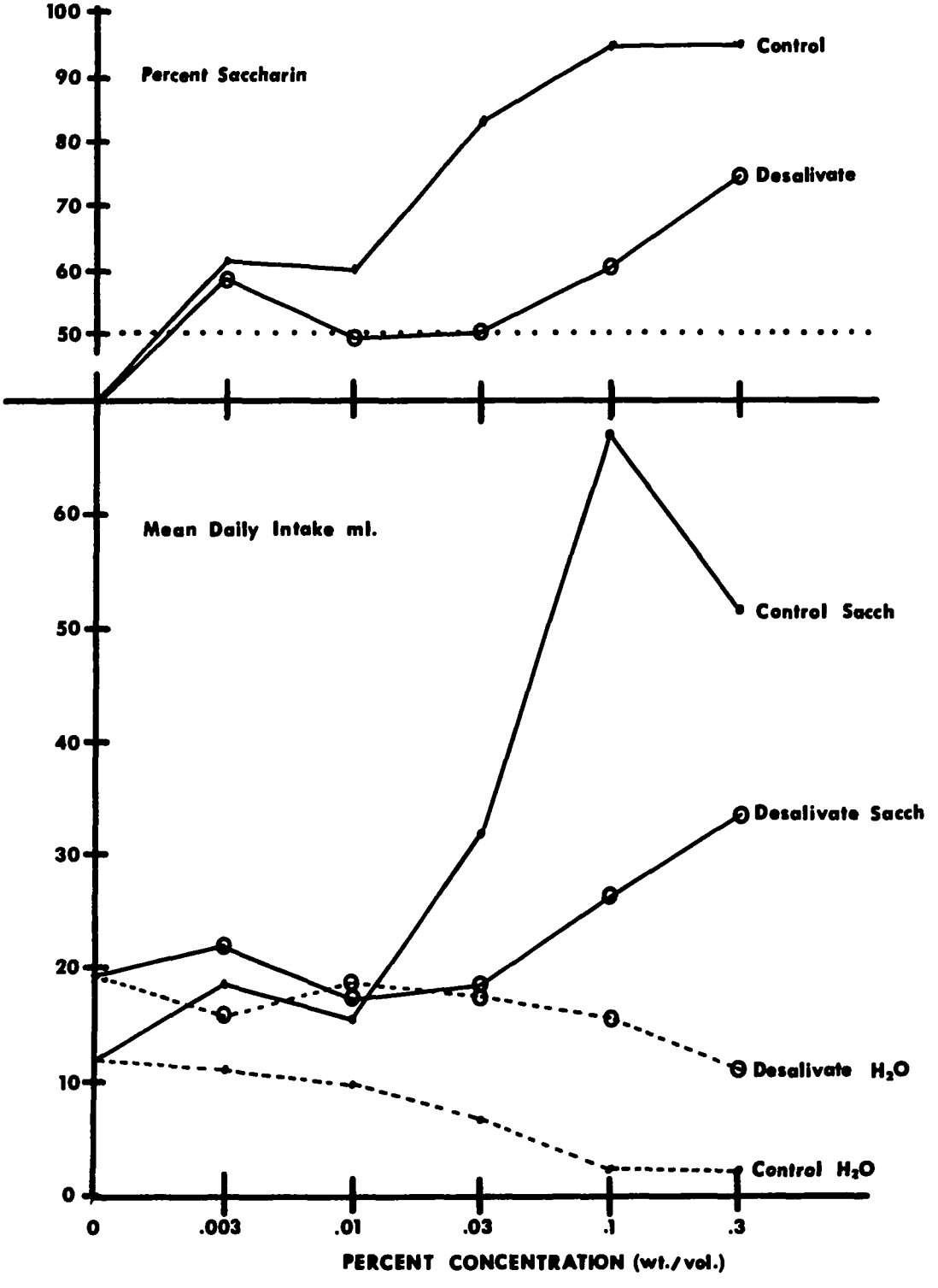
Results

Figure 2 Top shows percent saccharin intake across concentration.

Analysis of variance revealed a significant interaction between the absence or presence of salivary flow and the saccharin concentration ($F = 3.2$, $df = 4/40$, $p = .02$). Simple effects revealed that the concentration of saccharin solution reliably affected the per cent of saccharin drunk for desalivates ($F = 2.7$, $df = 4/40$, $p < .05$) and controls ($F = 9.13$, $df = 4/40$, $p < .01$). Both desalivates and controls showed the ascending portion of the preference. As concentration increased, the per cent of saccharin intake increased. The bottom graph shows that this preference increase was a result of each group drinking more saccharin and less water.

However, the desalivates showed a preference shift. Above .01%, saccharin preferences of the desalivates were significantly less than the controls ($F = 15.6$, $df = 1/10$, $p < .01$; $F = 5.6$, $p < .05$). Although preference did increase with concentration for the desalivates, the increase lagged behind that of the controls. Saccharin intake tended to be lower for the desalivates than the controls, while water intake was higher producing the lower preference.

Figure 2. Two-bottle preference tests in desalivate rats and control rats with increasing concentrations of sodium saccharin as the test solution


100
90
80
70
60
50
Percent Saccharin
Control
Desalivate
60
50
40
30
20
10
0
Mean Daily Intake ml.
Control Sacch
Desalivate Sacch
Desalivate H_2O
Control H_2O
0
.003
.01
.03
.1
.3
PERCENT CONCENTRATION (wt./vol.)

Experiment III

Saccharin preference was tested with and without food, to determine if this preference shift was the result of the masking effect due to prandial drinking as in Experiment I.

Method

Subjects used were the six desalivates and six controls from Experiment II. One concentration of sodium saccharin, .03%, was presented for 4 days without food, and 4 days with food. This is the concentration that produces the biggest difference in percent drunk between groups. Again, position of the solution was switched every day.

Results

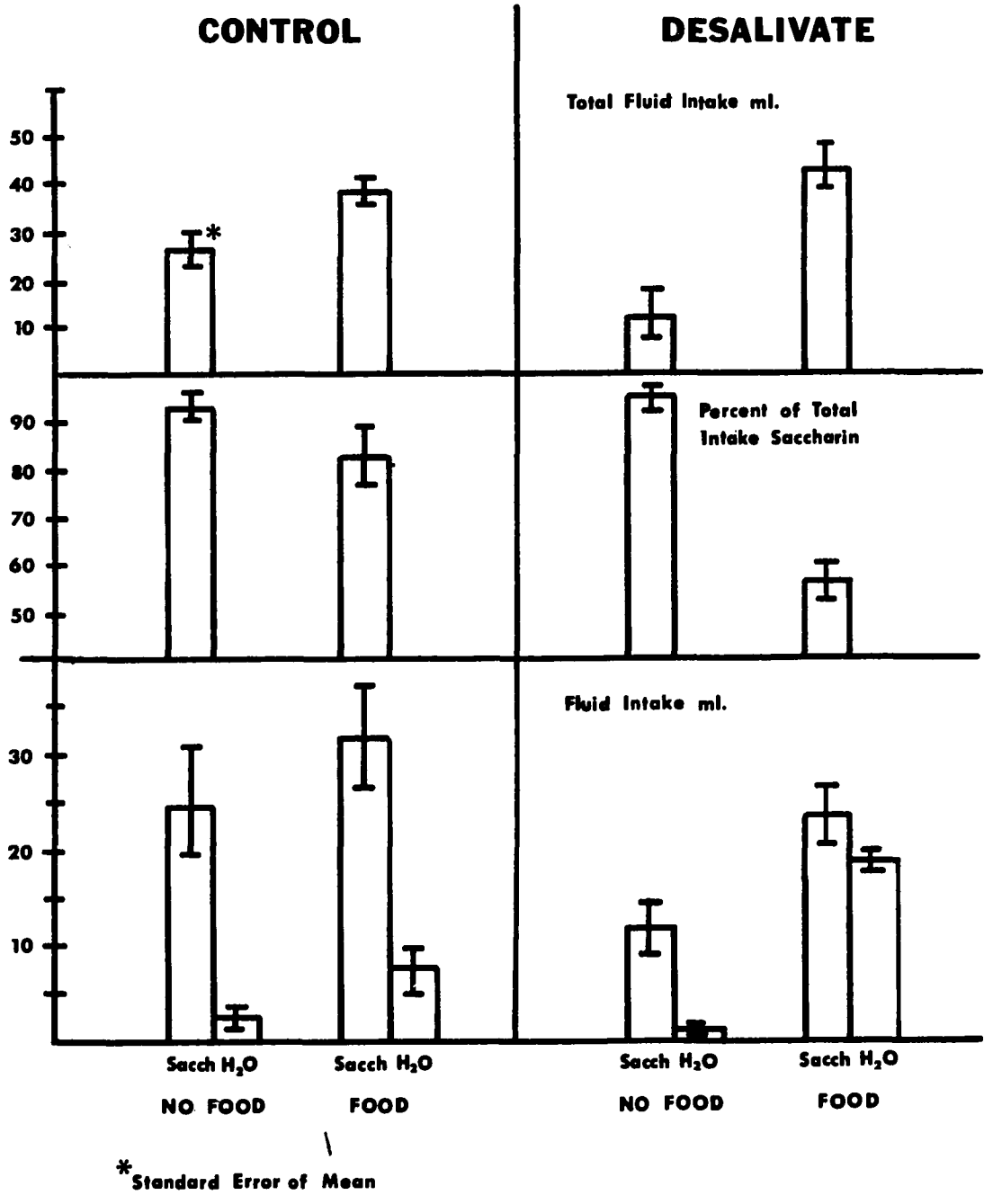
Intake

The top of Figure 3 shows mean daily total intake for desalivates and controls averaged over 4 days. Just as in the quinine experiment, total intake depends on the presence and absence of food ($F = 8.33$, $df = 1/10$, $p = .02$). Again, both groups were affected by the absence and presence of food (for desalivates, $F = 42.73$, $df = 1/10$, $p < .01$), but did not differ from controls when food was present ($F < 1$).

Preference

The middle of Figure 3 shows saccharin as a percent of the total intake for each four day period. Per cent saccharin was also influenced by the presence and absence of food ($F = 12.52$, $df = 1/10$, $p = .005$). Only preference for desalivates was affected ($F = 44.32$, $df = 1/10$, $p < .01$), with controls showing no difference in preference with and

Figure 3. Two-bottle preference tests in desalivate rats and control rats with .03% sodium saccharin as the test solution in the presence and absence of dry food



*Standard Error of Mean

without food ($F = 2.73$, $df = 1/10$, $p < .05$). Without food desalivates and controls did not differ in preference ($F < 1$), but with food, desalivates showed a significantly lower preference ($F = 14.16$, $df = 1/10$, $p < .01$). The lower figure shows that without food, both groups drank saccharin solution almost exclusively, although the desalivates drank less. With food, desalivates showed a proportionately greater increase in water intake while increasing saccharin intake. Controls continued to drink saccharin almost exclusively.

Discussion

The reduction in total intake by the desalivates in the absence of food was significant in this study but not reliably so in Experiment I. The amount of postoperative time seems to be important, since the depression of intake apparently becomes more reliable with increasing postoperative time.

Experiments I and III also differed in the test solution used. However, saccharin, because it makes a preferred solution, would be expected to increase total intake over aversive quinine. Instead saccharin shows a more reliable reduction in total intake. This fluid depression effect cannot be offset by a preferred solution.

The preference results demonstrated that the masking effect is not limited to NaCl and quinine solutions. The effect seems to produce a general deficit in taste discrimination.

Experiment IV

Saccharin, a solution generally reported as being sweet, showed a preference shift with desalivation. Sucrose, a different sweet

solution, was examined in this study to determine if this masking effect can be generalized to other preferred solutions.

There is an additional reason for this study. Kissileff (personal communication) reported a strong preference for sucrose even with desalivation. The possibility exists that there is no preference shift with sucrose. However, relative differences in preference for desalivates and controls were not examined. Such an analysis is important, since we demonstrated that even in desalivates a preference may persist even though there is a relative decrease in this preference. The next study, then, examined sucrose preference to see if desalivation can produce a loss in yet another sweet solution.

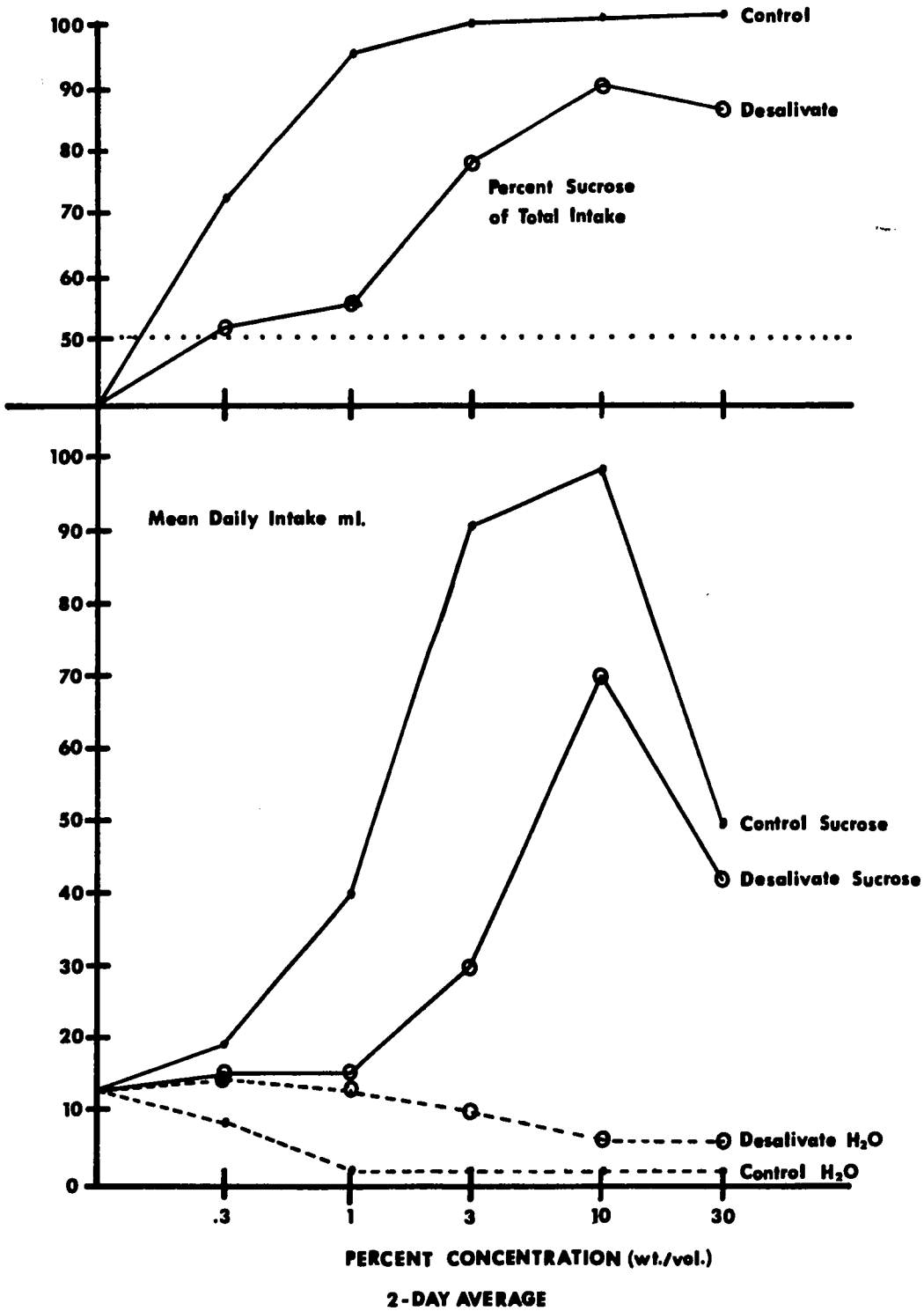
Method

Twelve albino rats from the previous study, six of them desalivated, served as subjects. In the same paradigm as Experiment II, an ascending series of concentrations were presented in two-bottle tests. The concentrations used were .3%, 1%, 3%, 10%, and 30%.

Results

Analysis of variance revealed a significant interaction between groups (desalivates vs. controls) and concentration ($F = 3.51$, $df = 4/40$, $p = .015$). Figure 4 Top shows per cent sucrose of total intake of desalivates and controls, while the bottom of the graph shows mean daily intake. Controls and desalivates were then examined separately. The controls showed the typical preference function with an increase in sucrose intake with concentration, up to a peak, followed by a slight decline. This increased sucrose intake combined

Figure 4. Two-bottle preference tests in desalivate rates and control rats with increasing concentrations of sucrose as the test solution


100
90
80
70
60
50
Control
Desalivate
Percent Sucrose
of Total Intake
100
90
80
70
60
50
40
30
20
10
0
Mean Daily Intake ml.
Control Sucrose
Desalivate Sucrose
Desalivate H2O
Control H2O
.3
1
3
10
30
PERCENT CONCENTRATION (wt./vol.)
2-DAY AVERAGE

with a decline in water intake, resulted in an increased per cent of sucrose intake, indicated by a significant concentration effect ($F = 8.22$, $df = 4/10$, $p < .01$). The desalivates, on the other hand, show an attenuated preference increase, although the ascending function begins to emerge at high concentrations. Therefore, while the concentration effect was significant ($F = 14.15$, $df = 4/10$, $p < .01$) preference under several concentrations was reliably lower than controls ($F = 22.84$, $df = 1/10$, $p < .01$; $F = 8.65$, $p < .05$). Water intake was higher for desalivates, but saccharin intake was lower than controls.

Discussion

These findings were very similar to the saccharin findings. In both instances the preference aversion function remained intact in both desalivates and controls. In both instances the desalivates drank relatively less of the preferred solution in comparison to water. Therefore, the loss in discrimination is not specific to one taste quality.

Experiment V

This experiment examined the loss in sucrose preference in the presence and absence of food to determine if this preference loss further parallels the loss in ability to discriminate quinine and saccharin.

Method

The subjects were the twelve rats from the previous study. They were presented with a 1% solution in a two-bottle situation for four days without food and four days with food. This concentration was the

one that produces the largest difference in per cent sucrose intake between groups in Experiment IV.

Results

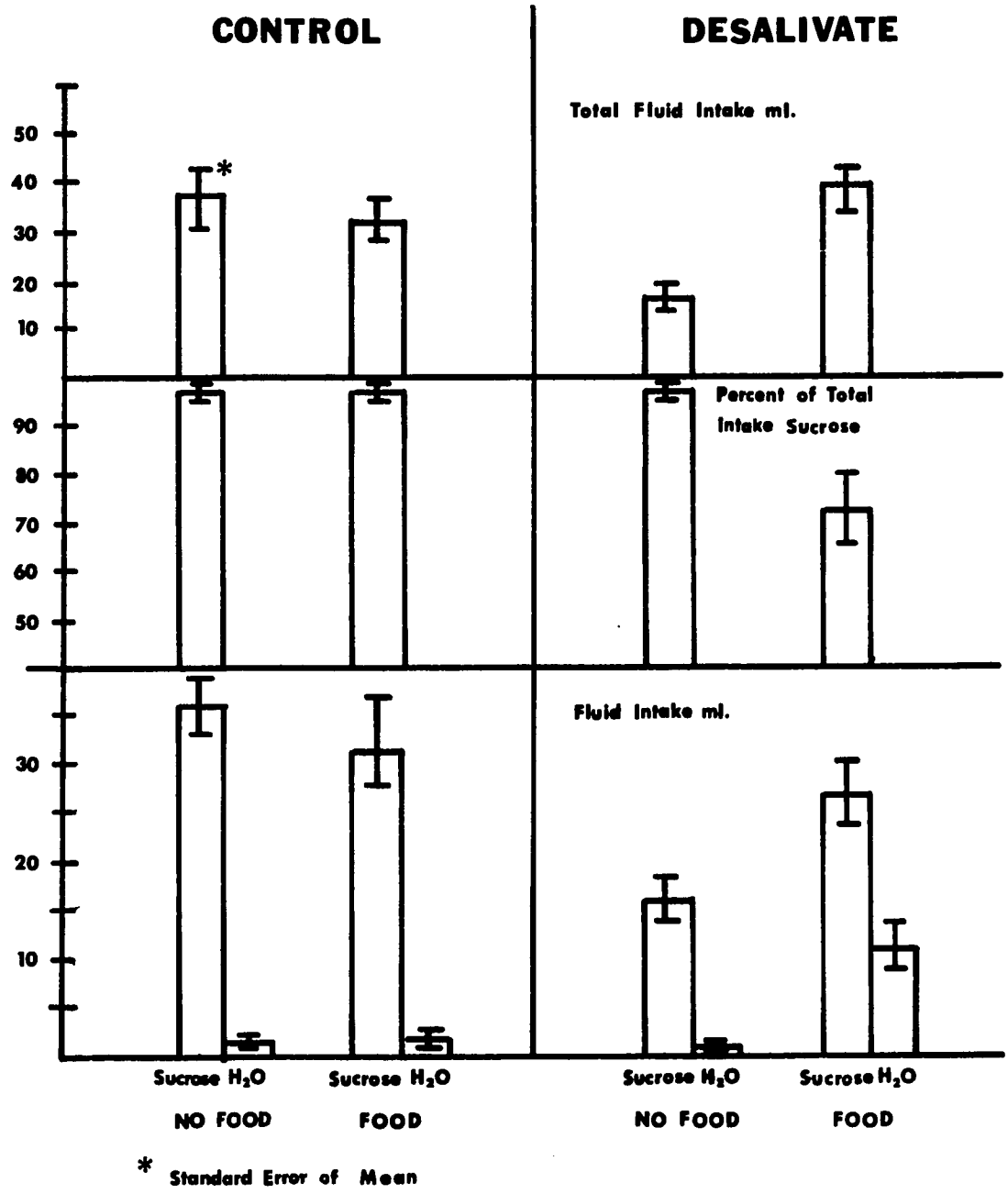
Fluid Intake

The top of Figure 5 shows total fluid intake for controls ($F = 14.2$, $df = 1.10$, $p = .004$). Analysis of variance of total intake revealed that the presence and absence of food by group (desalivates vs. controls) interaction was significant. Without food the desalivates drank significantly less than the controls ($F = 23.7$, $df = 1.10$, $p < .01$), and less than when food was available for the desalivates ($F = 22.5$, $df = 1/10$, $p < .01$). Intake of the controls was not affected by the presence or absence of food, nor was it different from desalivates when food was available ($F < 1$). Since the desalivates tended to weigh less than controls, a ratio of fluid intake to body weight was used to compare the two groups on the days when food was absent. Again, a reliable difference was found ($t = 4.4$, $df = 10$, $p = .002$).

Preference

The bottom of Figure 5 shows mean daily intake of sucrose and water for each 4 day period. The middle of Figure 5 shows per cent sucrose intake. The presence and absence of food reliably affected preference as indicated by a significant food by group interaction ($F = 10.8$, $df = 1/10$, $p < .008$). Specifically while sucrose intake is lower in the desalivates, water intake is even lower, resulting in proportionately the same amount of sucrose ingest in both groups ($F < 1$).

Figure 5. Two-bottle preference tests in desalivate rats and controls with 1% sucrose as the test solution in the presence and absence of dry food



* Standard Error of Mean

With food, however, sucrose and water in desalivates increased but water showed a greater increase in desalivates, resulting in a lower preference ($F = 23.8$, $df = 1.10$, $p < .01$). Controls did not show such changes in intake and preference did not change ($F < 1$).

Discussion

Total Intake

When food was absent, desalivates drank less than controls. By the third experiment this effect was very reliable.

Although the investigation of this fluid depression effect was not the purpose of these studies, certain conclusions can be made. First the depression was not a result of the lower body weight of the desalivates. Experiment V confirmed this finding. Fluid intake/grams body weight was also significantly lower. Also in Experiments III and V but not I, differences in intake were significant indicating that the effect was more reliable. The effect did not seem to be a result of overhydration from the excessive drinking during the period when food was present. In Experiments III and V again when the depression effect was most reliable, desalivates did not differ significantly from controls in total intake when food was present.

Because the effect was more reliable in Experiments III and V than in Experiment I, it suggests that some factor associated with the passage of time may have been involved. One possibility is the development of an efficient prandial drinking pattern. An animal that acquires prandial drinking does persist in the pattern when such drinking becomes unnecessary (Chapman and Epstein, 1970). An animal that must

maintain food-associated drinking rather than regulatory drinking may persist in this pattern even beyond the occasion for food-associated drinking. Without food there would subsequently be little drinking. Indeed prandial drinkers do not respond as readily to gastric loading (Kissileff, 1969B).

In the presence of food, desalivates drank excessively, at least in the first experiments. In the last experiments, intake did not differ significantly from controls. Personal observation of the drinking behavior of these animals revealed that they were still showing the prandial drinking pattern. Apparently they were more efficient drinkers, requiring smaller drafts to wet their mouths. Indeed both the lower intake with and without food may be a result of a development in prandial drinking efficiency.

Preference Behavior

Experiment I demonstrated that, first, the shift in quinine aversion seen with desalivation (Vance, 1965) is, like the shift seen in salt preference (Kissileff, 1967), dependent on the presence of dry food. In addition this loss in discrimination is not specific to solutions only associated with the taste qualities of bitterness and saltiness, for saccharin and sucrose which are associated with a sweet taste will also show such a preference loss. The effectiveness of this phenomenon with the latter solution is striking because sucrose also has postingestional consequences.

Experiments I-V do not support the hypothesis that such a preference loss is a result of a modification of the receptor response. Such findings are consistent with the masking hypothesis. The presence

of dry food provides the occasion for prandial drinking. The close proximity of eating and drinking may result in the taste of the food masking the taste of the test solution.

Concentration of the test stimulus is important. With increasing concentration of the test solution, a preference or an aversion is more likely to be demonstrated by the desalivates. Therefore the preference-aversion functions of saccharin and sucrose remained intact, although they were shifted to higher concentrations. In addition the preference-aversion function of NaCl and the aversion function of quinine were also present in Vance's study (1965), although they were again shifted to higher concentrations. We also observed that performance is not totally eliminated with desalivation. Indeed, the persistence of the function may explain why Kissileff (personal communication) failed to find a preference loss for sucrose. He may have examined a concentration that would yield a strong preference even after masking.

Finally there is no evidence of an increased preference with desalivation. The reduced intake of sucrose without food in Experiment V is of special interest because Vance (1965) had reported an enhanced sucrose intake even without food present. One possibility is that the reduction in fluid intake seen in the desalivates may have offset any preference enhancing effects. However such a factor would also have operated in the Vance study.

Experiment VI

Experiments I-V tested the validity and generality of the masking hypothesis. These experiments demonstrated that the loss in

preference seen with desalivation is dependent on the presence of dry food, just as the masking hypothesis would predict. Presumably the close occurrence of eating and drinking in the prandial drinking pattern induced in desalivates with dry food resulted in the food taste masking the taste of the test solution.

If the loss in preference is considered an indirect effect of desalivation (prandial drinking leading to masking) rather than a direct effect (change in receptor response), then a preference loss is predicted if the prandial drinking pattern is induced without changing salivate conditions.

In this experiment, the prandial drinking pattern was induced without desalivation by introducing a reinforcement contingency for such behavior. The prandial drinking pattern was schedule induced by the contingency that food delivery was indicated only if preceded by licking. If the masking effect only accounts for the preference loss, such a contingency alone should produce a preference loss in a two-bottle situation.

Method

Subjects

The subjects were six adult female albino rats with a mean weight of 246.5 grams. The animals were housed in their steel mesh home cages when not in the testing apparatus.

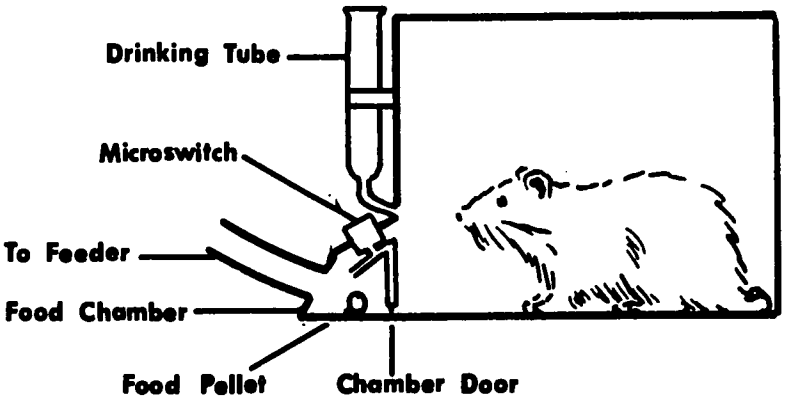
The Test Apparatus

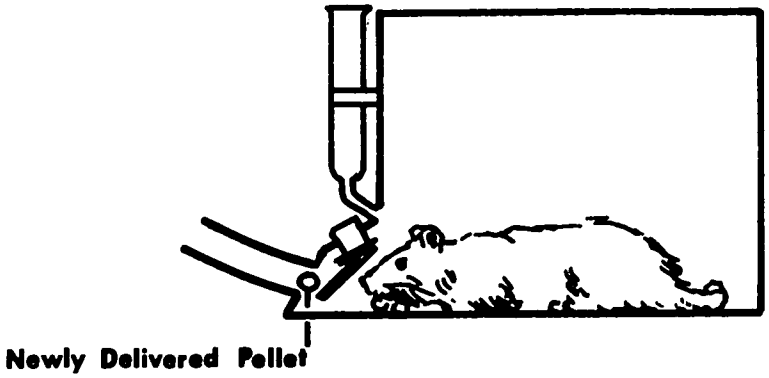
The test apparatus is pictured in Figure 6. When the plexiglass door was pushed, and allowed to spring shut, the microswitch activated

Figure 6. Test apparatus for schedule induced prandial drinking

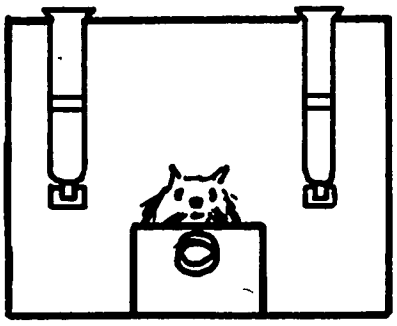
TEST CHAMBER

CROSS SECTION





FRONT



a pellet dispenser which delivered a 45 mg Noyes pellet. The sequence began then with a pellet in the food tray. The rat pushed the door and got the pellet. When the door closed another pellet was delivered.

Mounted on each side and equal distance from the door were 100ml plastic cylinders accurate to the nearest millimeter. The drinking spouts were glass and rested in front of and flush with plexiglass guards with .167 X .25 cm. oval openings. The guards prevented nose pokes from activating the drinkometer.

Data Measurement

Drinking activated a drinkometer circuit and a cumulative recorder. Pellet delivery was indicated by discrete blips on the cumulative recorder while drinking produced upward excursions of the pen. The drinkometer and feeder also activated a contingency circuit that counted only when feeding followed drinking. In this way a quantitative measure of prandial drinking was made possible by recording the number of drinking-eating alternations in ratio to the number of pellets delivered.

Procedure

The animals were deprived to 80% body weight and magazine trained. For four days after acquiring the habit, they were tested for 1 1/2 hours each day with a .01% quinine solution and distilled water. This concentration was found to give a consistent aversion for all animals in this short testing interval. The animals were fed just enough chow pellets in the home cage to maintain them at 80% body weight. After training, however, they were allowed to seek their own weight. They were not water deprived.

On the fifth day, the contingency was introduced. A pellet was produced by a door push only if drinking preceeded the attempt. The contingency was maintained for six days until all animals acquired the habit. Only water was available for drinking. To initiate the habit the animals were water deprived in the home cages for four days. Once the habit was acquired, the animals were tested for four days with quinine and water and they were again allowed water in the home cages.

Five days later, the contingency was removed and the behavior was allowed to extinguish. The animals were tested for four days after the contingency ended. In addition, four desalivates were tested for two days for comparative data.

The procedure may be summarized as follows:

Magazine training - approximately three days

Quinine test session, no contingency - four days

Contingency acquisition - six days

Quinine test session with contingency - four days

Quinine test session without contingency (extinction - four days)

Results

Eating-Drinking Behavior

All animals developed the operant response within 3 days. With the contingency acquisition was slower. By the sixth day all animals had acquired the habit. The deprivation condition, however, finally initiated the behavior. These animals showed a high fluid intake. Whether this was due to the water deprivation condition cannot be determined, but total intake remained high throughout the contingency, even after the deprivation condition was removed (see Figure 8).

The graphs show the contingency performance at different stages (see Figure 7). Before training, pellet deliveries, as indicated by the event marks, occur in trains, indicating meals, followed by the upward excursions of the stepper, indicating licking. With training, pellet deliveries initially occurred at wider intervals and were each followed by licks. As training continued, pellet intervals shortened and became completely interspersed with licking, indicating the development of the prandial drinking pattern.

A comparison of the records of the desalivate animals on the contingency, especially late in training, shows the similarity. In addition, the alternation ratio, the ratio of the number of alternations to the total number of food pellets, of the animals on the non-contingency schedule never exceeded 10%, but the desalivates showed a ratio of from 30% to 50%. The alternation ratio of these intact rats on the contingency schedule was of course 100%.

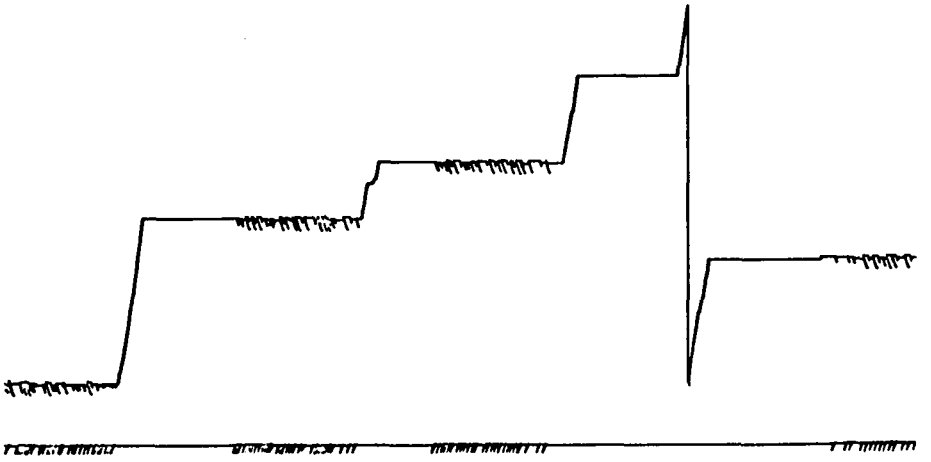
After the extinction phase, the prandial drinking pattern had disappeared, and intakes had dropped to the precontingency level.

Aversion Behavior

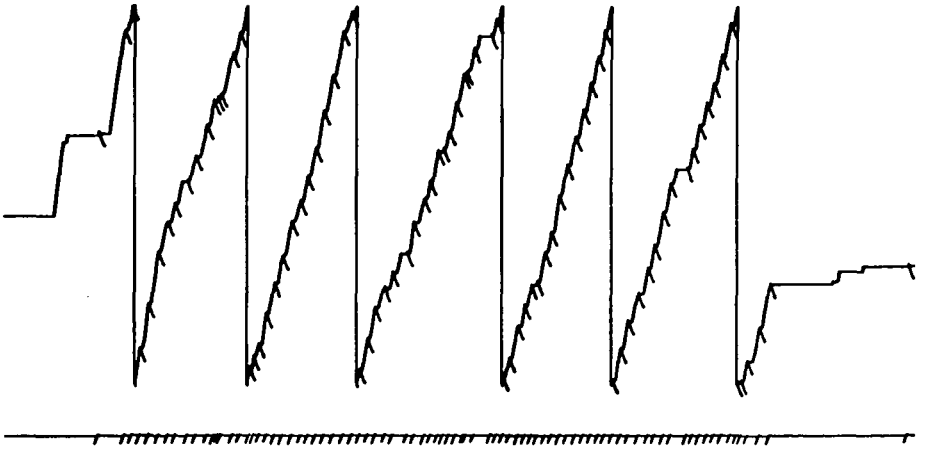
Figure 8 shows quinine expressed as a percentage of total intake and mean fluid intake. The presence and absence of the contingency reliably affected quinine aversion ($F = 22.4$, $df = 2/10$, $p = .0002$). Without the contingency all animals showed a strong quinine aversion. No more than 5 ml. of quinine was drunk by any one animal in a test session. With the contingency, quinine aversion was dramatically reduced, as quinine intake increased. For example, one animal drank 15 ml. of quinine in one session. When the contingency was eliminated, quinine

Figure 7. Cumulative recorder records of animals in the contingency schedule and desalivate rats. Upward excursions represent licks and event marks represent pellet delivery.

NON-CONTINGENCY



CONTINGENCY



DESALIVATE

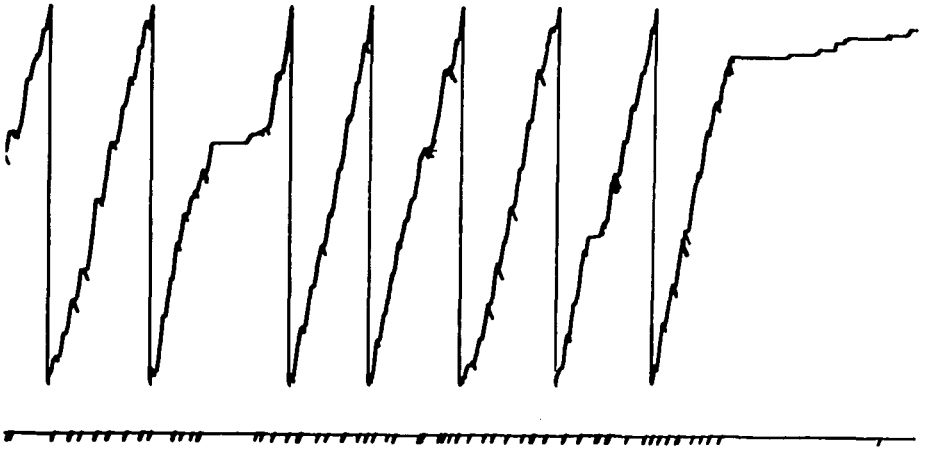
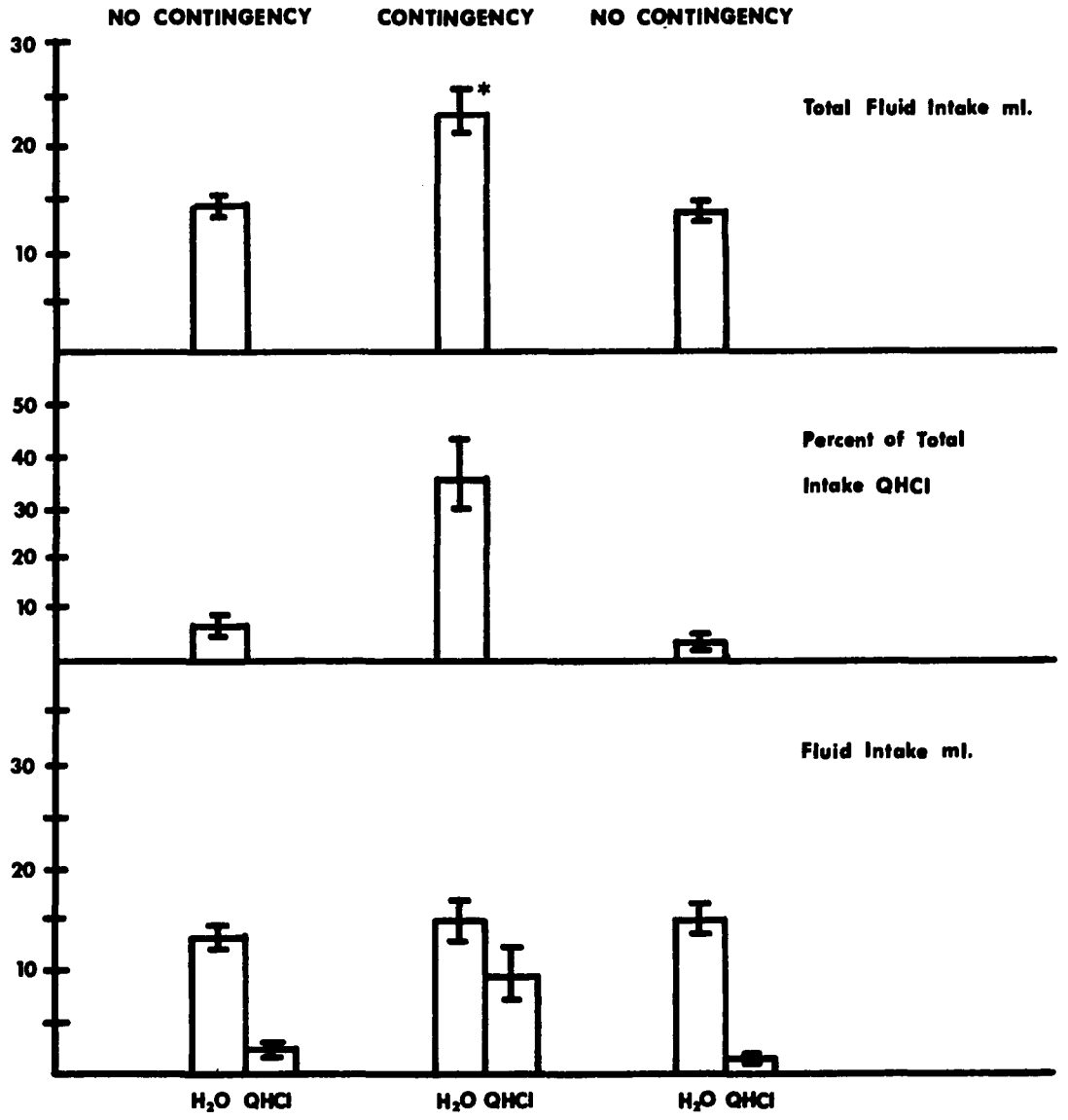


Figure 8. Two-bottle preference tests in desalivate rats and controls with .01% QHCl as the test solution with and without a contingency schedule



*Standard Error of Mean

aversion returned to normal. The Newman Keuls post-hoc test revealed that a significantly higher proportion of quinine was drunk when the contingency was present than when it was absent ($p < .01$). The proportion of quinine intake did not differ significantly in the sessions without the contingency, the period before the contingency or the extinction period ($p > .05$).

Discussion

These findings demonstrated that the long term changes in preferences and aversions seen with desalivation can be accounted for entirely by a factor secondary to the removal of saliva, the prandial drinking pattern that these animals demonstrate. When this drinking pattern is operantly induced, without the salivary flow being interrupted, a preference loss develops. The loss in sensitivity seen with desalivation therefore would appear to result from the closeness in time of eating and drinking such that the taste of the food masks the taste of the test solution rather than from any permanent modification of the receptor response.

One source of evidence that is not consistent with this hypothesis is the conditioned polydipsia research (Falk, 1964). Excessive fluid intake and a prandial drinking pattern similar to that seen in desalivates also occurs with conditioned polydipsia. However, no preference loss is seen (Falk, 1966; Stricker and Adair, 1966).

The drinking pattern in conditioned polydipsia does differ in some respects from prandial drinking. The crucial difference is that in conditioned polydipsia a time interval of approximately a minute is

mandatory between the operant response and pellet delivery. Such an interval may prevent the necessary close occurrence of eating and drinking for masking.

Experiment VII

Previous studies demonstrated the significance of diet texture in the development of prandial drinking. Wet diets prevent the occurrence of prandial drinking by making it unnecessary (Epstein et al., 1964; Vance, 1965). Dry powder delays the development of prandial drinking because of the greater difficulty in acquiring the pattern with such a diet (Vance, 1965). The loss in preference seen in Experiments I-V should also be prevented with the appropriate diet texture, if prandial drinking is indeed the basis for such preference changes. More significantly, however, such a manipulation could be the basis for examining any hypothesized direct effect on desalivation on preference such as the reported preference enhancement effect. The absence of the confounding influence of prandial drinking would insure that any such preference changes would be a direct result of the absence of a fluid environment in the mouth.

This experiment examined NaCl preference when diet texture was manipulated to prevent prandial drinking. It was previously hypothesized that in the absence of prandial drinking, desalivated rats would show a salt preference enhancement (Lawson, 1969).

If the preference enhancement effect requires a dry mouth, the dry powder should produce such a response without the confounding influence of prandial drinking since desalivate animals on such a diet

develop the drinking pattern much later than animals on Purina Lab Chow pellets (Vance, 1965). It was predicted that the animals given the lab chow would show an immediate preference loss. Animals given the dry powder would show a preference enhancement, followed by a preference loss as prandial drinking developed. Animals on a wet mash diet should also show a high preference but no preference loss.

Method

The subjects were 12 adult female albino rats, averaging 304.9 grams in weight. They were randomly assigned to three groups of four animals each. One group was given Purina Lab Chow, another group was given Purina Lab Chow obtained in powdered form. A third group was given a wet mash consisting of 1.25 parts distilled water to one part powder by weight.

These animals were given a choice between .45% saline solution and water in two-bottle tests with drinking tubes switched daily. After four days all subjects were desalivated by ligation of the ducts of the four major salivary glands. Preference tests were continued for an extended observation period. The lab chow group was terminated earlier than the others for participation in the next study.

Observations were made of body weight and fluid intake. Food intake was also measured by using cardboard trays to catch waste. Except for the wet mash, food wasted was allowed to dry, scrapped up without feces, and weighed to the nearest 10th of a gram.

Results

Lab Chow Group

These animals showed a strong preference before desalivation (see Figure 9). After desalivation, prandial drinking developed, as indicated by several factors. Animals first stopped eating and lost weight. Personal observations revealed that they has difficulty chewing. After four days on the average, however, intake showed an increase. Body weight and the amount of food eaten also increased. However wastage also increased.

Preference behavior showed a consistent decline. Intake of the salt solution initially increased, but water intake showed a delayed but progressive increase until the intake of both did not differ greatly.

Dry Powder

These animals showed a strong preference before desalivation as well. After desalivation these animals reduced food intake while weight steadily dropped. Fluid intake was somewhat lower but preference remained although it was not excessive. Finally, intake, amount eaten, and weight all increased. Wastage was high, even higher than the lab chow group. At this period preference showed a steady decline, just as in the lab chow group.

Wet Mash

Before desalivation these animals showed a low but consistent preference. After desalivation, unlike the other animals, no immediate changes in weight, intake or wastage developed. However these animals did show a slight weight loss for several days. Note that these animals must be over-hydrated, a necessary consequence to maintain caloric

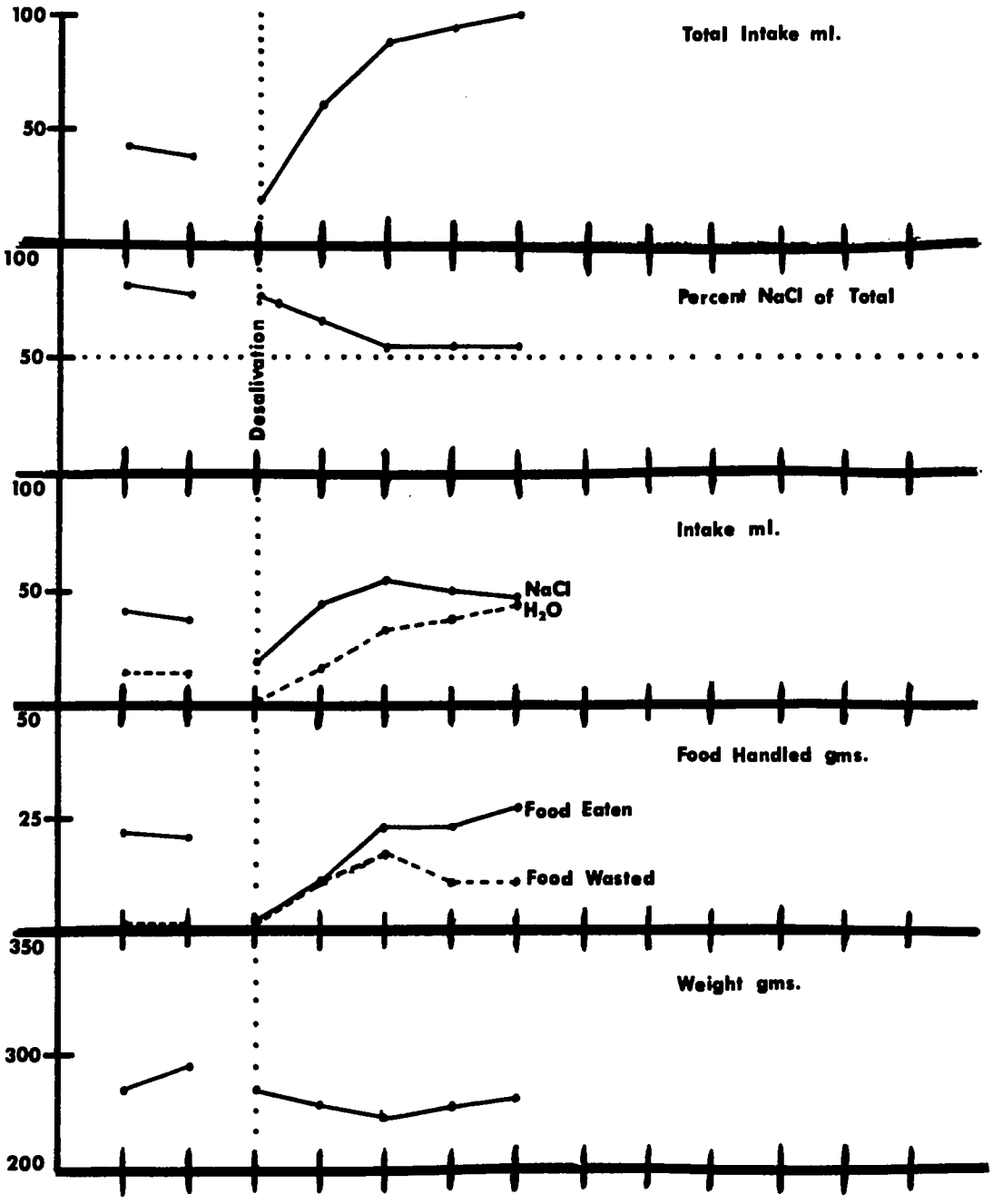
Figure 9. Effects on desalivation and type of diet on two-bottle preference for .45% NaCl

9A rats given chow pellets

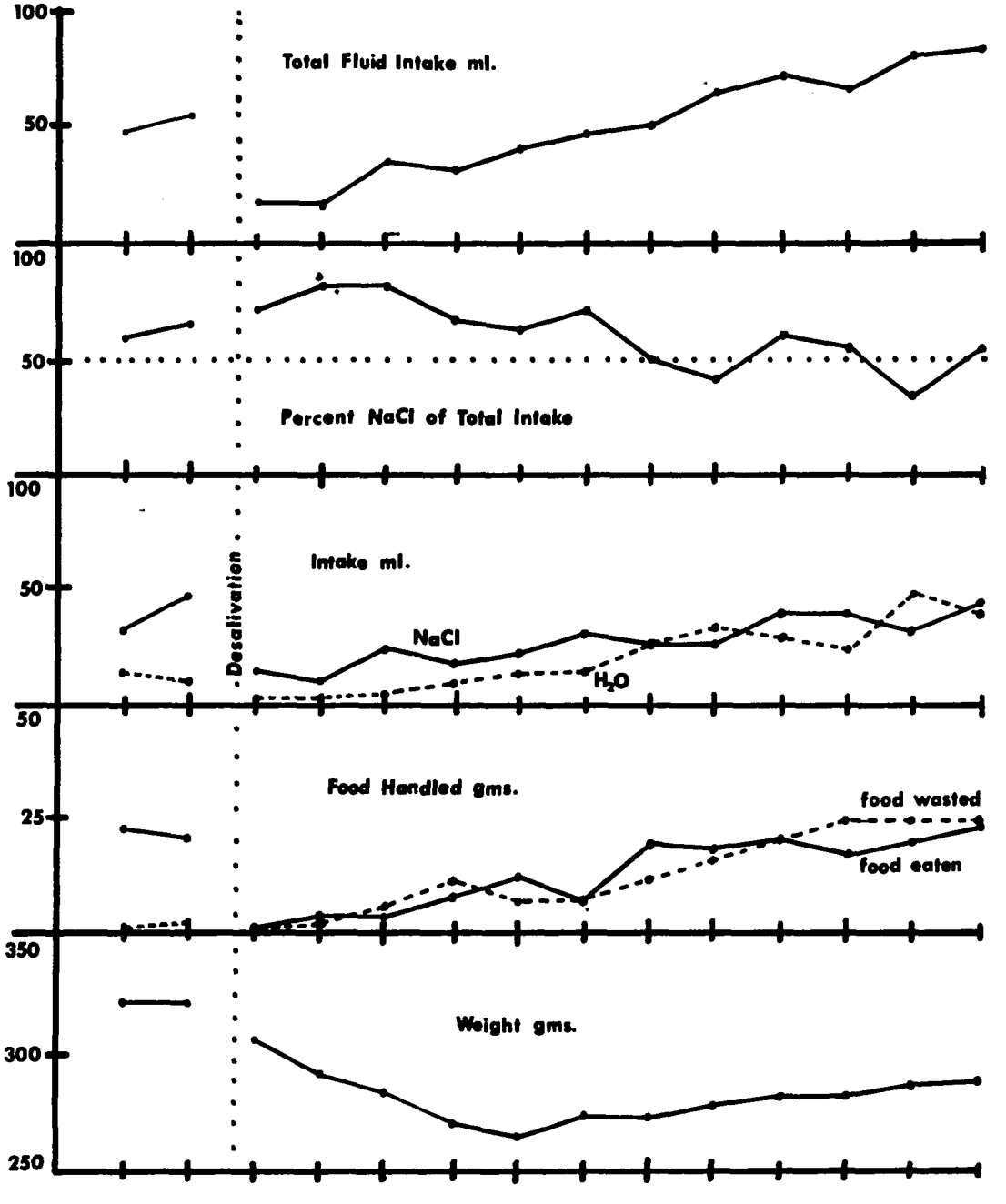
9B rats given powder

9C rats given wet mash

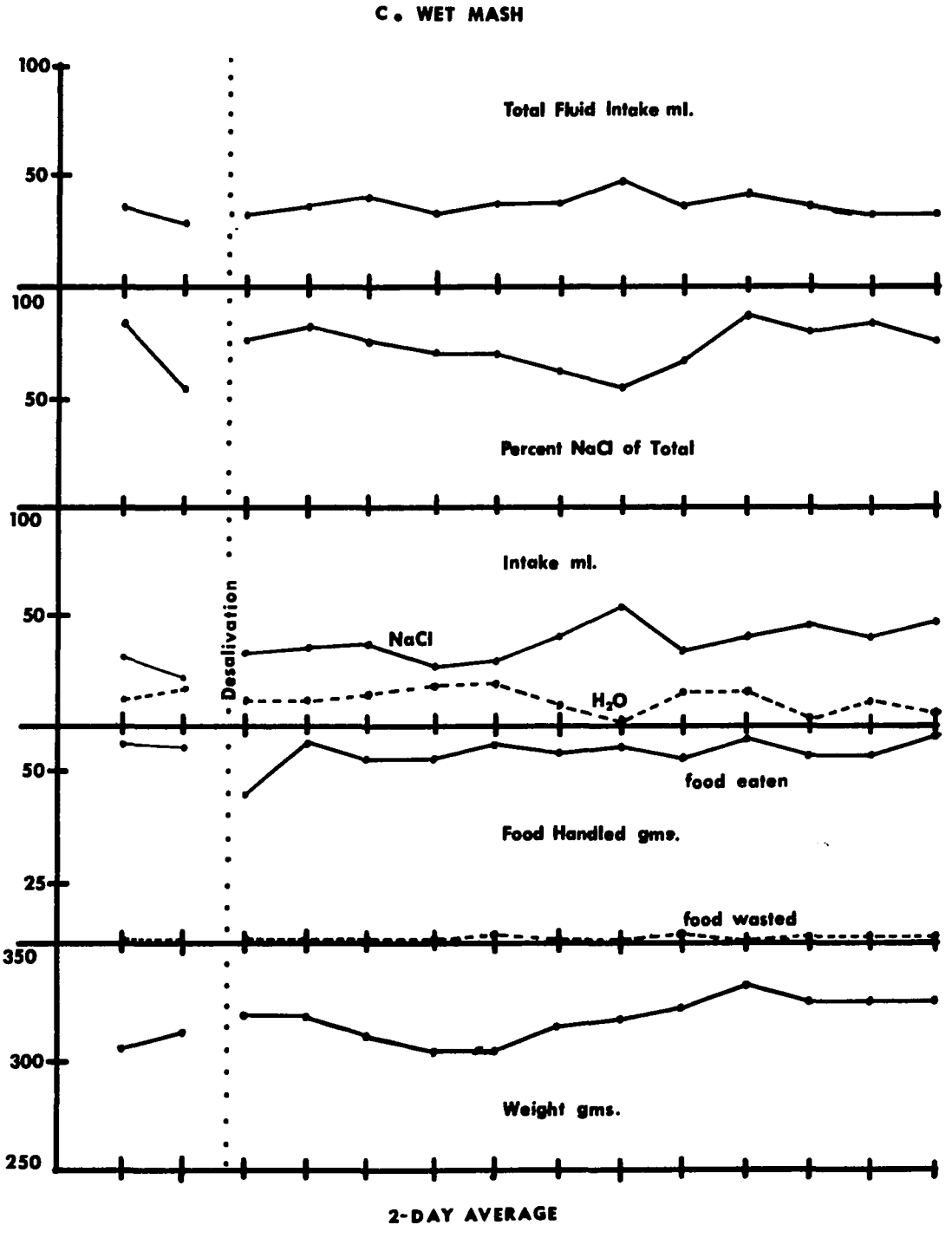
A. CHOW PELLETS



B. DRY POWDER



2-DAY AVERAGE


C. WET MASH
100
50
Total Fluid Intake ml.
100
50
Percent NaCl of Total
100
Intake ml.
50
Desalivation
NaCl
H_2O
50
food eaten
Food Handled gms.
25
food wasted
350
300
Weight gms.
250
2-DAY AVERAGE

balance. However only one animals in this group showed a consistently low intake.

Preference in these animals did not decrease. In fact there was a small increase.

Discussion

These findings confirmed the observations of the previous studies in demonstrating the significance of the prandial drinking pattern for the preference changes seen in desalivates. With desalivation the most prominent preference change was a sustained preference loss. This preference loss occurred only when dry food was available. Only the animals on lab chow and dry powder showed such a loss.

Previous researchers (Stricker, 1970; Vance, 1965) had used high fluid intake, excessive food wastage, "recovery" of eating, and the regaining of weight as indicators of prandial drinking. With dry chow pellets, the preference loss occurred soon after desalivation. The phenomena associated with prandial drinking appeared soon afterwards as well. The dry chow powder delayed the appearance of the phenomena associated with prandial drinking as well as the preference loss.

As noted earlier the first experiments were confounded by the influence of deprivation effects on preference behavior, because they involved the removal of food reward as a test of the masking hypothesis. These experiments demonstrated that food removal is unnecessary. This study involving a wet mash and dry powder diet demonstrated that when food texture is manipulated so that prandial drinking is prevented from occurring, desalivates will show a normal preference. Together these

findings provide additional support for the masking hypothesis, that desalivates show a preference loss because the taste of the test solution is masked by the food eaten because of prandial drinking.

Again there was no evidence of a preference enhancement effect. The wet mash group did show a small but progressive increase. However the time course of the increase was different from Vance's (1965) increase and certainly not as large, indicating that other factors besides desalivation were responsible.

Experiment VIII

The previous studies examined the role of the fluid environment of the mouth by determining the preference changes that occurred with saliva removal. In this study, the appropriate fluid environment was returned to salivaless animals in order to determine the significance of saliva for preference behavior.

Desalivation was proposed to have two effects: a direct influence on taste sensitivity and a loss in sensitivity resulting from the prandial drinking pattern. Both of these effects should be modified or abolished by oral infusion. The direct effect was assumed to result from the absence of an adapting solution on the tongue (see Introduction). Indeed Vance (1970) reported changes in the preference of intact rats when the adapting fluid on the tongue is modified by oral infusion. Prandial drinking is believed to be a result of the difficulty of eating dry food with a dry mouth. Oral infusion also will abolish the prandial drinking pattern (Kissileff, 1969B). Presumably preference changes induced by prandial drinking will also be abolished.

In this experiment desalivated and intact rats were infused intra-orally. Any preference differences between desalivates and controls should be eliminated since the proposed factors underlying these differences were either controlled (i.e. direct effect of the nature of the fluid environment) or eliminated (i.e. prandial drinking).

As was previously stated, the psychophysical research on humans showed that changes in taste sensitivity depends on the concentration of the solution washing the tongue, a finding consistent with the proposal that the solution serves as an adapting stimulus. Vance (1970) however found that the concentration of the solution infusing the mouth was not a factor in preference behavior. In view of these contrasting results, this experiment reexamined the role of the concentration of the infusate. Water was used as the infusate in the first part of the study and a .9% NaCl was used as the other infusate. An adaptation hypothesis would predict that preference behavior should depend on the infusate concentration.

Method

Subjects

Five female adult albino rats of approximately the same age served as subjects. Four animals began the experiment, while another was added in the second part of this experiment. Two of these rats that began the experiment were naive. All other rats were desalivates from the chow pellet groups of Experiment VII. They had been desalivates for ten days before the intraoral tubes were implanted.

Surgery

Intraoral tubes were implanted, utilizing a technique described by Kissileff (1969A) which itself was a modification of the Epstein nasogastric tube (Epstein, 1967). The rats were anesthetized with nembutal and a midline incision on the head exposed the top of the skull. A bent metal tube of about 27 ga. stainless steel was centered on the skull and reinforced with head screws and dental cement. The incision was then extended down the middle of the face and slightly to one side in front of the eye. Forceps were then pushed under the skin, around the oribtal bone and out through the soft palate. A polyethylene fistula, P.E. 90, was flanged at one end and fitted with a polyethylene washer. The other end was pushed through the hole in the roof of the mouth and directed subcutaneously to the metal tubing with needle-nose forceps. The fistula was then cemented to the tubing. A polyethylene screw socket was glued with epoxy to the other end of the metal tubing.

The animals were then allowed to live in their home cages for recovery and for the subsequent test sessions. During recovery, animals were given a solution of the antibotic tetracyclin. Sucrose was added to facilitate drinking. Treatment was stopped after the fourth postoperative day, when swelling had subsided.

Under ether anesthesia the animals were then connected to the injection device for oral infusion. A plastic assembly consisting of a screw cap fitted with a 28 ga. steel tube was screwed to the head assembly. Teflon tubing was fitted tighly over the steel tubing projecting from the other end of the assembly. Silastic reinforced this junction. The teflon tubing then passed through the punched hole

plywood on top of the cage, and to a Harvard syringe pump. A counter-weight arrangement allowed the animal freedom of movement. This apparatus is pictured in Figure 10.

Procedure

Subjects were given two-bottle tests with a .45% NaCl and water. Bottle positions were switched daily. Animals were tested under three conditions: no infusion, infusion with distilled water, and infusion with a .9% NaCl. The no infusion condition lasted for four days, and was considered the baseline condition. The first experimental condition involved oral infusion of water at the rate of 1 ml./hr. over a period of eight days. The second experimental condition involved oral infusion of salt solution at the same rate for a period of 4 days.

The experiment can be summarized:

Four control days - no infusion

Eight test days - water infused

Four test days - .9% NaCl infused.

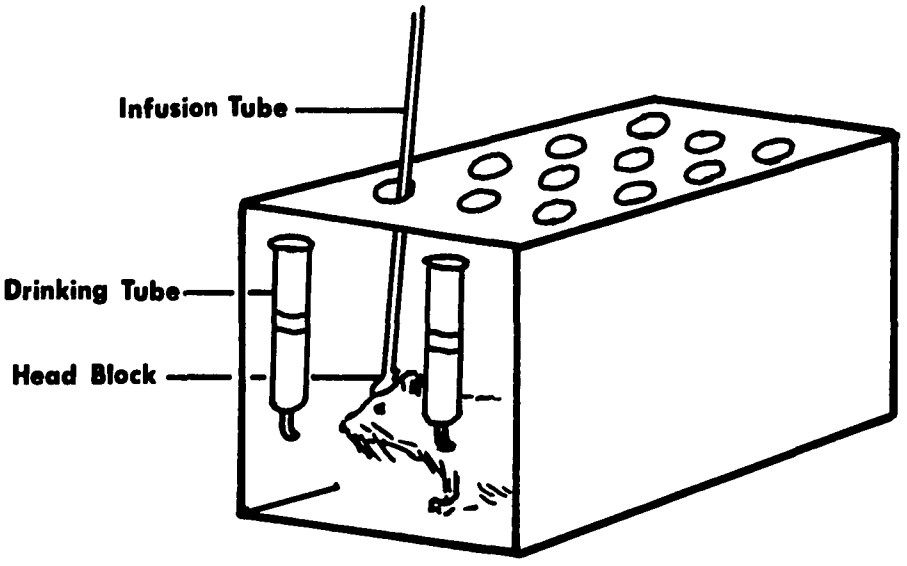
Before the infusion of salt solution, one control, Control #3, lost the headpiece and was destroyed. Another animal, Desalivate #6, was added, but not as a replacement, since it was a desalivate, but to get more information on preference effects in desalivates. This animal was a subject in the previous experiment, and the pre-infusion data is from that experiment.

Measurements

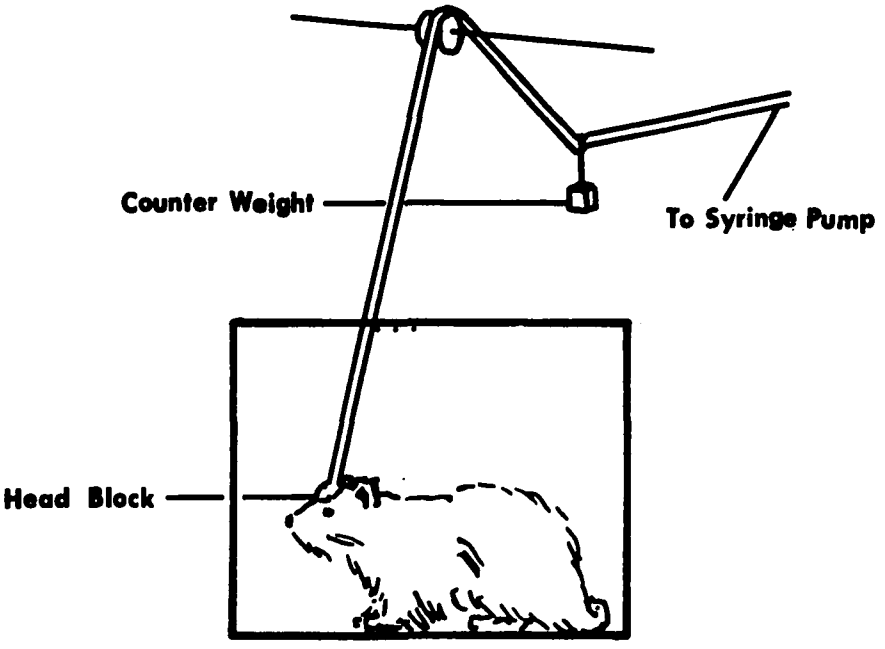
Twenty-four hour fluid intake was measured. In order to determine the presence of prandial drinking, food intake and food wastage was

Figure 10. Test chamber for oral infusion

INFUSION SYSTEM and TEST CHAMBER



CROSS SECTION



measured. Also feeding efficiency was determined by calculating the per cent of the total intake that was wasted:

$$(\%\ \text{wasted} = \frac{\text{food wasted}}{\text{food wasted} + \text{food eaten}} \times 100) \ .$$

In addition, personal observations were made of the animals while they fed.

Results

Before infusion, the control animals showed a substantial preference for the salt solution (see Figure 11). Preference was well over 50% throughout this test session. The desalivate animals continued to show no salt preference and a higher total fluid intake which they had demonstrated before infusion tubes were implanted. In addition the desalivates wasted more food than the controls. Loss of preference, high fluid intake, and high amounts of food wastage have all been used as indicators of prandial drinking (Lawson, 1969; Stricker, 1970; Vance, 1965).

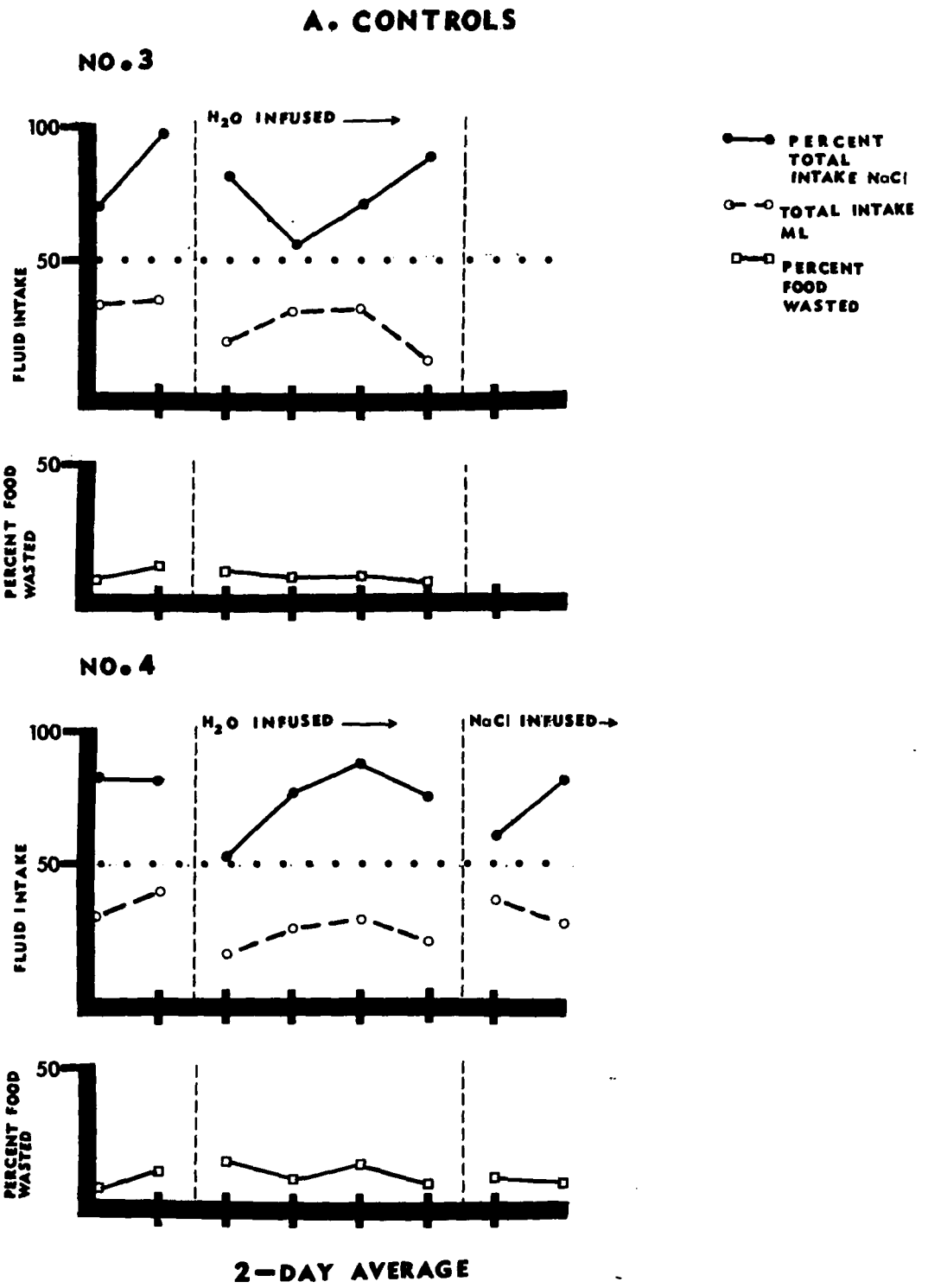
Activating the pump initially disturbed the animals. The animals froze in a crouching position from either the noise or from the fluid passing into the mouth. However, they seemed to adapt within an hour and became normally active.

With influsion of distilled water, both controls showed a decrease in preference. Control #4 showed an immediate decrease and Control #3 showed a more gradual decline, until the salt solution made up approximately 50% of total intake. Preference for both animals then gradually increased until it reached its previous high levels.

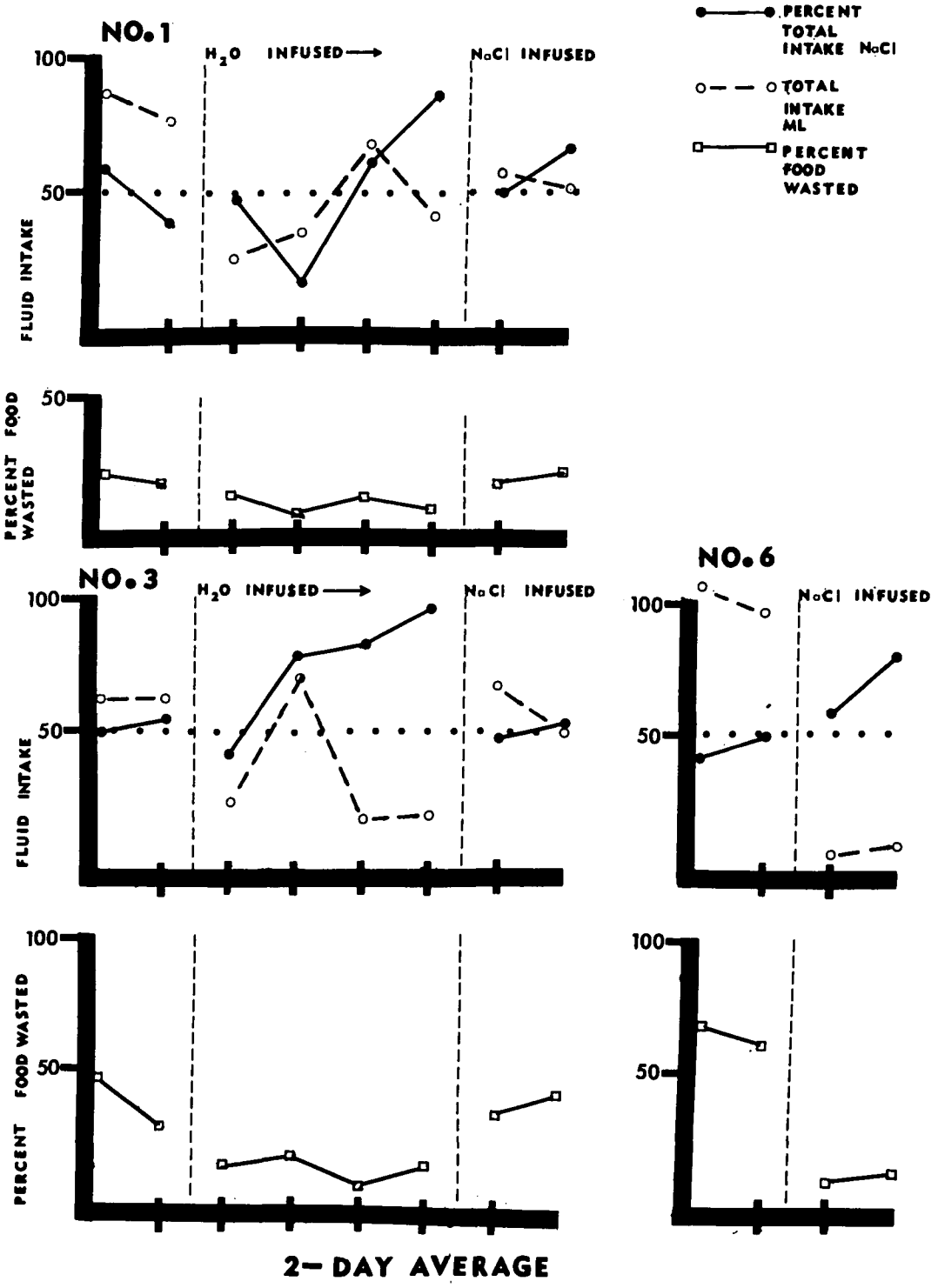
Figure 11. Two-bottle preference tests in desalivate rats and controls with a .45% NaCl as the test solution and oral infusion of H_2O or .9% NaCl

11A. Controls

11B. Desalivates


A. CONTROLS
NO. 3
100
50
FLUID INTAKE
H_2O INFUSED
PERCENT TOTAL INTAKE NaCl
TOTAL INTAKE ML
PERCENT FOOD WASTED
50
PERCENT FOOD WASTED
NO. 4
100
50
FLUID INTAKE
H_2O INFUSED
NaCl INFUSED
50
PERCENT FOOD WASTED
2—DAY AVERAGE

B. DESALIVATES



2— DAY AVERAGE

The controls also drank somewhat less water, a finding that is not surprising since these animals were infused with 24 ml. of fluid per day. However the reduction in the amount drank was not great enough to compensate for the additional fluid chronically infused.

Both desalivates eventually showed an increase in salt preference. Preference in both desalivates ultimately reached the high levels of the controls. Preference for each desalivate reached highs of 94.2% and 85% for a two day period and the controls showed highs of 86.7% and 87.2%.

The total intake fluctuated, but it generally was lower than the pre-infusion level. The per cent of food wasted also fluctuated but was generally reduced. Such data suggests that prandial drinking was disrupted, although not consistently so. Indeed observations of the eating and drinking behavior revealed that these animals did not alternate chewing of the food with drinking as frequently as they did in the pre-infusion session. Prandial drinking was disrupted but not abolished. The fluctuations in each of the different measures of prandial drinking do not always correspond.

With infusion of salt solution, the control animal again showed an initial reduction in preference, followed by a return to a high preference. Intake was not reduced.

The two desalivates, #1 and #3, showed a substantial drop in preference, almost to the pre-infusion level, although preference was somewhat higher in desalivate #1. Total intake and percentage food wasted also increased to the pre-infusion levels, suggesting that prandial drinking had re-emerged.

Desalivate #6 did not show a preference before infusion. In addition this animal was a strong prandial drinker as demonstrated by both a high total intake and a high proportion of food wastage. With infusion, preference increased until it was well beyond 50%. Intake and wastage were greatly reduced suggesting that prandial drinking was abolished. Direct observation of the eating-drinking pattern confirmed this conclusion.

Discussion

Infusion has two major effects in this study. One effect was a transient depression in salt preference. This effect was more notable in the controls, probably because the desalivates began with a low initial preference. The other effect was the re-emergence of preference behavior in the desalivates.

Let us first examine the preference depression effect, because such a finding is significant if the concept of saliva serving as a constant adapting stimulus is valid. As we stated previously, Vance (1965) proposed that the salt preference enchancement he found occurred because the constant adapting simulus, saliva, was absent. The critical factor was the adapting influence of salivary sodium on the sodium chloride solution being tasted. Support had come from human studies in which an adapting salt solution influenced taste discrimination and quality of a salt solution being tested. In the rat, Vance (1970) had demonstrated that a wide range of concentrations of infused salt solutions had depressed salt preference, thus supporting an adaptation hypothesis. These findings of Experiment IV also suggested a preference

depression with infusion, but unlike the Vance study the effects were transient. Since Vance only presented the means for his observation periods, a similar analysis of his data might have revealed that his results are consistent with these.

There are several points about the findings of Experiment IV and the Vance study that are inconsistent with an adaptation hypothesis as the basis for the preference enhancement effect. First the effects were transient and far shorter (within four days) than the period of time in which preference was enhanced in Vance's (1965) study (at least 40 days). Secondly, in this study as well as in the Vance (1970) study, preference was depressed even when the concentration of the infusate was below the concentration of the test solution. Yet experiments demonstrating the influence of adapting solutions on salt taste, with the concentration of the adapting solution below that of the test solution, were considered analogous to and served as a basis for explaining the preference enhancement seen with desalivation (Vance, 1965).

The infusion findings are inconsistent with electrophysiological and psychophysical findings which show an enhancement in the response to salt solution when the concentration of the adapting solution is below that of the test solution (see Introduction). In fact the discrepancy between adaptation research and the infusion research suggest that oral adaption may not be the basis for the depression in salt preference at all. The infusate is swallowed, producing postingestional consequences, as indicated by the reduced total intake. Preference may also have been reduced by such factors.

Mook (1963, 1969; Mook and Kozub, 1968) demonstrated that the post-ingestional consequences of a salt solution may immediately affect preference behavior. One factor that he proposed, a postingestional hydration factor, may account for these results. He found that salt preference to some extent results from increased intake of the salt solution over water because the salt solution is less hydrating than water. Perhaps in the oral infusion situation, the infused fluid produced a constant hydration that depressed salt intake. Indeed Mook did find that preference was depressed by intragastric infusion of water or low concentrations of salt solution. The infusion data then is more consistent with findings from postingestional infusion than with taste adaptation research.

The second effect of infusion found in this study is the re-emergence of preference in the desalivates. Previously we proposed that the preference associated with desalivation results from the prandial drinking pattern that these animals show. The prandial drinking pattern itself is an acquired adpative response to eating dry food with a dry mouth. Experiment IV confirms that preference will emerge if a wet mouth makes prandial drinking unnecessary, provided that a preference exists. Indeed the initial low preference after infusion may be a result of the consequences of infusion rather than prandial drinking, which, by all indicators except preference, was absent.

Prandial drinking however was not totally and consistently abolished throughout infusion, as demonstrated by the variability within the different measures of prandial drinking. Preference in fact was present during the presence of this weak prandial drinking, as

demonstrated by several indicators. Such a finding has implications for the preference enhancement effect. Vance (1965) noted that the enhanced preference he reported was confounded with the development of the prandial drinking pattern. Perhaps in Vance's study, soon after desalivation, the prandial drinking which had just begun to emerge was, like the disrupted prandial drinking pattern in this study, too weak to mask preference but strong enough to enhance intake. The increased intake would then have magnified preference. Thus the increased salt preference may in itself occur because of prandial drinking.

The failure to consistently abolish prandial drinking may be contrasted with Kissileff's (1969B) finding that small squirts of water preceding eating readily abolishes prandial drinking. This difference in findings may be accounted for by Stricker's (1971) observations of animals with lateral hypothalamic lesions. He found that these animals, which are prandial drinkers, can eat without water present, indicating that saliva is not absent. He concluded that the absence of a salivary reflex flow to the presence of food rather than the absence of saliva alone accounts for prandial drinking in such animals. Kissileff's infusion technique, which made a squirt of water contingent on eating, may be equated to reflex salivation, while continuous infusion, as in this study produces an animal more like the lesioned rat rather than a normal rat. The failure to completely abolish prandial drinking then may be a result of the use of continuous rather than contingent infusion.

Another notable finding is the re-emergence of prandial drinking with salt solution infused. Such a finding is paradoxical because the

salt solution is even more like saliva and therefore should be more effective in depressing prandial drinking than water alone. However prandial drinking was abolished in Desalivate #6, indicating that the presence of salt solution does not in itself initiate prandial drinking. One immediate explanation for the re-emergence of prandial drinking is that prandial drinking may have reappeared during the period with no infusion between infusion sessions. The pattern was then well established and required a longer session or higher rate of infusion to be abolished.

However there are several reasons why this explanation is questionable. First Stricker (1970) found that partially desalivated rats did not become prandial drinkers in spite of apparent difficulties in eating. Only total desalivation will produce prandial drinking. Prandial drinking therefore is an atypical pattern of ingestion that is apparently not readily induced.

Secondly, Kissileff (1969B), using a similar flow rate as this study, though with food dependent infusion, found that oral infusion more effectively depressed prandial drinking if the animal had had experience with oral infusion. If anything, these animals should show less prandial drinking at the time of NaCl infusion.

Finally the argument may be raised that, with time, prandial drinking would be eliminated and preference re-emerge. However an immediate drop in total fluid intake and per cent wastage occurred with water infusion in these desalivates, and with salt infusion in the intact rat and the new desalivate. Both of these latter animals showed

preference enhancements within four days, the total time period of the saline infusion sessions.

Another possibility that may account for the different effects under saline infusion involves the stimulus properties of the salt solution and water, and is related to Stricker's (1971) conclusion that reflexive salivation is required for abolishment of prandial drinking. Isotonic saline may provide less tactile stimulation to the mouth because of its similarity to the indigenous fluid environment. Perhaps because the saline infusion contains less water, it may not be as "wet", and therefore less stimulating to the mouth. Whatever the reason, the infused saline solution may provide less of a cue to prevent prandial drinking, if indeed prandial drinking is prevented in the intact rat by some stimulus property of a wet mouth as Stricker seems to suggest. In the intact rat, the variation in salivary flow with eating probably serves to prevent initiation of prandial drinking. With constant infusion perhaps a "wetter" mouth is required.

These findings demonstrate that infusion has at best a transient influence on preference. Again the primary finding is the re-emergence of preference in the absence of prandial drinking, demonstrating that the preferences seen after desalivation are a result of the prandial drinking pattern.

CONCLUSION

The Masking Effect

Experiments I-VI demonstrated that the major effect of desalivation was a reliable loss in preferences and aversions resulting from the prandial drinking. The first studies demonstrated that this masking effect, produced a nonspecific loss in taste discrimination such that preferences and aversions were depressed for a variety of solutions. In addition the masking effect occurs across a range of concentrations for many solutions, although with a high enough concentration strong preferences and aversions may be demonstrated. This masking effect was initially assumed to result from a permanent modification of the gustatory receptor response due to desalivation (Vance, 1965). Indeed Halpern (1967) had proposed that this discrimination deficit was a result of a change in the type of receptors present. An asalivary environment would modify the functional characteristics of the taste receptors and consequently preference behavior. These studies however demonstrated that the conditions associated with testing were as crucial as desalivation. When food was present a preference loss occurred. Without food there was no loss. Such a finding does not support the concept of a change in the receptor response.

Finally, this preference loss occurred only when prandial drinking developed regardless of the presence of food. Indeed the sixth experiment demonstrated unequivocally that this effect occurs when prandial drinking is induced, even without desalivation.

Such findings support the masking hypothesis. Prandial drinking occurs with desalivation because of the difficulty of eating dry food with a dry mouth. This pattern of drinking results in the animal eating small drafts of food followed immediately by small drafts of water. The close occurrence of eating and drinking resulted in the food taste masking the taste of the test solution. The crucial variable therefore is not salivary flow itself, but the adaptive response that develops when a rat must eat dry food with a dry mouth.

The Preference Enhancement Effect

Desalivation has been reported to produce an enhancement in preference behavior in addition to the preference loss.

Vance (1965) demonstrated that the absence of saliva enhanced preference. Desalivation produced an increase in salt preference and an increase in intake for a sucrose solution. Such findings would indicate that changes in the fluid environment do produce a preference enhancement. No preference enhancement however was found in the present experiments when the preference depressing effect of prandial drinking was controlled by removing dry food or substituting diets that do not initiate prandial drinking. In the first group of experiments, when food was absent, relative preference for sucrose and saccharin did not exceed that of the controls. However the preference was high and a ceiling effect may have been operating. Vance (1965) did find an increased sucrose intake, when food was absent with desalivates.

Indeed our findings are consistent with the failure of others to find a preference enhancement for salt (Kissileff, personal

communication) and sugars (Brill and Maller, 1972).

Previously reported preference enhancement effects could also be explained by the use of dry food in testing desalivates. In Vance's study (1965), food was presented in one part of the daily test session and sucrose in another. The animals may have used sucrose as a liquid food because of the difficulty in eating the dry food. The high concentrations used (10%) would further contribute to caloric drinking rather than ingestion because of taste.

The salt preference results may relate to the degree of the prandial drinking. Experiment VIII gave some indication that preference may return if prandial drinking is disrupted, even if the pattern is not abolished.

A previous study with atropine-induced desalivation (Lawson, 1969) demonstrated that the masking effect occurred as the prandial drinking pattern developed. With a weak pattern, preference was slightly enhanced. In Vance's demonstration the enhanced preference occurred soon after desalivation, when prandial drinking was still emerging. The enhanced preference then may represent an exaggeration of the normal or even a slightly enhanced preference as a result of a prandial drinking pattern that is strong enough to increase intake, but too weak to mask the taste of the test solution.

Total Intake

Experiment I as well as Experiment VII demonstrated that desalivation results in an increased intake when dry food is present. The results with different dietary conditions, i.e. chow pellets, dry powder

and wet mash food confirmed what Epstein et al. (1964) and others have found, that this increased intake is a result of drinking to wet a dry mouth in order to ingest dry food. In addition he found that this increase is not permanent. Given time intake will fall, presumably because of greater efficiency in eating.

We also confirmed earlier reports that, in contrast to the predictions of the "dry mouth" theory of thirst, desalivation reduces fluid intake in the absence of food. Stricker and Wolf (1969) suggested a direct role of salivary flow, that it serves to initiate drinking. However these findings, especially Experiments I-V, suggest that the depression in fluid intake is a result of the development of prandial drinking, and not just the absence of saliva. Note that no reduction in intake occurred in the wet mash group in Experiment VII when desalivates had not experienced prandial drinking because they were given a diet that did not require the response.

Implications

Concern has risen over the role of the fluid environment of the mouth in ingestion. Specifically, interest in the salivary environment has developed because it is one factor that may account for the oral control of specific hungers. The invariance of the gustatory response creates a problem in accounting for such behavior as increased salt appetite because of salt deficiency. However salivary flow has been proposed as one answer. The salivary environment which reflects to a great extent the internal environment was believed to modify the taste response through adaptation or a similar mechanism.

However Vance (1965) demonstrated that desalivation does not affect salt appetite. We could not find any direct effects of desalivation on preference. In addition there are several reasons why preference behavior should not be affected, even if there were a direct effect of desalivation on taste. First, as Pfaffmann (1967) suggested, the drinking of the test solution would flood the receptors and consequently salivary effects. Next salivary flow itself is negligible in the rat when the glands are not stimulated artificially (Schneyer and Schneyer, 1967). Finally, salivary flow is only one portion of the mouth's fluid environment. A significant portion is contributed by the mucous membrane of the mouth (Montgomery, 1931).

Again these experiments do not exclude the possibility that salivary flow has no direct effects on preference. Indeed 24 hour preference tests may be too insensitive a measure. Perhaps such measures as a brief exposure technique may be more applicable. Indeed such a measure would be more similar to human psychophysical techniques which do demonstrate that the adapting solution on the tongue is important for taste, but which also are short term tests.

Nor do these experiments indicate that salivary flow need not be considered in research involving preference and ingestion. In fact we show just the opposite. As a cautionary measure, the role of salivary flow must be considered when ingestive behavior is investigated.

The findings especially have implications when anticholingergic drugs such as atropine are used to elucidate the central mechanisms underlying ingestion for such drugs reduce salivary flow. Soulairac (1959) proposed that there is a cholinergic mechanism of carbohydrate

metabolism because atropine produced an enhancement in glucose intake and a depression in solid food intake. Such a finding could have also reflected the difficulty of animals eating with the dry mouth produced by atropine injections. Just as in Vance's study, the glucose may have been used as the source of calories because of the difficulty of eating solid food.

Soulairac (1969) also reported increased intake with atropine injections, a finding inconsistent with the general observation that atropine depresses intake. Epstein (see Discussion, Soulairac, 1969) criticized Soulairac's contention that some cholinergic thirst mechanism was involved and suggested that prandial drinking accounted for these results, especially since Chapman and Epstein (1970) has found that atropine readily produced prandial drinking. Soulairac reported increased salt intake. But he also used a diet of 1/3 water. Because of the diet, his animals may have developed a weak prandial drinking pattern, such that intake is increased and preference is enhanced rather than masked.

In addition the consequence of desalivation must also be considered in investigations involving damage to the lateral hypothalamic area. Such lesions have been widely used as a means of elucidating the bases of ingestion, but these lesions also produce salivary deficits (Hainsworth and Epstein, 1966; Kissileff and Epstein, 1969). Stage III of recovery of these animals from aphagia is a dry food aphagia that results from the difficulty of eating dry food with a dry mouth. These animals then develop prandial drinking and the problems of the masking effect are then present. Indeed Kissileff (1967) reported that these

animals may show a preference loss for salt due to prandial drinking. Initially the erroneous conclusion had been made that the loss in salt appetite was a result of the brain damage (Kissileff and Epstein, 1962).

Recently, the stages of recovery seen after lateral hypothalamic lesions have been found to be a recapitulation of the normal ontology of eating and drinking in the developing immature rat (Teitelbaum, Cheng, and Rozin, 1969). In addition prandial drinking is acquired just as in the lesioned rat (Kissileff, 1971). Prandial drinking and associated phenomenon then are not limited to rather atypical experimental situations, but occur normally in the rat. Therefore the cautionary note of salivary involvement in any reported preference may include a variety of investigative situations.

BIBLIOGRAPHY

Bare, J. K. The specific hunger for sodium chloride in normal and adrenalectomized white rats. Journal of Comparative and Physiological Psychology, 1949, 42, 242-253.

Bartoshuk, L. M., McBurney, D. H. and Pfaffmann, C. Taste of sodium chloride solutions after adaptation to sodium chloride implications for the "water taste". Science, 1964, 143, 967-968.

Blair-West, J. R., Coghlan, J. P., Denton, D. A. and Wright, R. D. Effects of endocrines on salivary glands. In C. F. Code (Ed.) Handbook of Physiology, Sec. 6 Alimentary Canal, Vol. II, Secretion. Washington, D. C.: American Physiological Society, 1967.

Brill, W. A. and Maller, O. Selection and intake of sugars by desalivated rats. Behavioral Biology, 1972, I, 442-445.

Carpenter, J. A. Species differences in taste preferences. Journal of Comparative and Physiological Psychology, 1956, 49, 139-144.

Carr, W. J. The effect of adrenalectomy upon the NaCl taste threshold in the rat. Journal of Comparative and Physiological Psychology, 1952, 45, 377-380.

Chapman, H. W. and Epstein, A. N. Prandial drinking induced by atropine. Physiology and Behavior, 1970, 5, 549-554.

Cohen, J. and Ogdon, D. P. Taste blindness to pheno-thio-carbomide and related compounds. Psychological Bulletin, 1949A, 46, 490-498.

Cohen, J. and Ogdon, D. P. Taste blindness to phenyl-thio-carbomide as a function of saliva. Science, 1949B, 110, 532-533.

Cragg, L. H. The relation between sourness and the pH of saliva. Transactions of the Royal Society of Canada, Sec. III, 1937, 31, 7-13.

deWardener, H. E. and Herxheimer, A. The effect of a high water intake on salt consumption, taste threshold, and salivary secretion in man. Journal of Physiology (London), 1957, 139, 53-63.

Epstein, A. N. Feeding without oropharyngeal sensations. In M. R. Kare and O. Maller (Eds.), The Chemical Senses and Nutrition. Baltimore: The Johns Hopkins Press, 1967, pp. 263-280.

Epstein, A. N., Spector, D., Samman, A. and Goldblum, C. Exaggerated prandial drinking in the rat without salivary glands. Nature, 1964, 201, 1342-1343.

Falk, J. L. Studies on schedule-induced polydipsia. In M. J. Wayner (Ed.), Thirst. Oxford: Pergamon Press, 1964, pp. 95-113.

Falk, J. L. Analysis of water and NaCl solution acceptance by schedule-induced polydipsia. Journal of the Experimental Analysis of Behavior, 1966, 9, 111-118.

Greene, E. C. Anatomy of the Rat. New York: Hafner, 1959.

Hainsworth, F. R. and Epstein, A. N. Severe impairment of the heat induced saliva spreading in rats recovered from lateral hypothalamic lesions. Science, 1966, 153, 1255-1257.

Halpern, B. P. Some relationships between electrophysiology and behavior in taste. In M. R. Kare and O. Maller (Eds.), The Chemical Senses and Nutrition. Baltimore: The Johns Hopkins Press, 1967, pp. 213-242.

Harriman, A. E. and MacLeod, R. B. Discriminative thresholds of salt for normal and adrenalectomized rats. American Journal of Psychology, 1953, 66, 465-471.

Henkins, R. I., Gill, J. R., Jr. and Bartter, F. C. Studies on taste threshold in normal man and in patients with adrenal cortical insufficiency: The role of adrenal cortical steroids and of serum sodium concentration. Journal of Clinical Investigation, 1963, 42, 727-735.

Henkins, R. I. and Solomon, D. H. Salt-taste threhold in adrenal insufficiency in man. Journal of Clinical Endocrinology and Metabolism, 1962, 22, 856-858.

Kissileff, H. R. Loss of salt preference in rats drinking prandially. American Zoologist, 1967, 7, 789.

Kissileff, H. R. Food-associated drinking in the rat. Journal of Comparative and Physiological Psychology, 1969A, 67, 284-300.

Kissileff, H. R. Oropharyngeal control of prandial drinking. Journal of Comparative and Physiological Psychology, 1969B, 67, 309-319.

Kissileff, H. R. Acquisition of prandial drinking in weaning rats and in rats recovering from lateral hypothalamic lesions. Journal of Comparative and Physiological Psychology, 1971, 77, 97-109.

Kissileff, H. R. and Epstein, A. N. Loss of salt preference in rats with lateral hypothalamic damage. American Zoologist, 1962, 2, 116.

Kissileff, H. R. and Epstein, A. N. Exaggerated prandial drinking in the recovered lateral rat without saliva. Journal of Comparative and Physiological Psychology, 1969, 67, 301-308.

Lawson, W. B. Effects of atropine-induced desalivation on salt preference. Paper presented at the meeting of the Eastern Psychological Association, Philadelphia, April, 1969.

McBurney, D. H. and Pfaffmann, C. Gustatory adaptation to saliva and sodium chloride. Journal of Experimental Psychology, 1963, 65, 523-429.

McCance, R. A. The effect of salt deficiency in man on the volume of the extracellular fluids, and on the composition of sweat, saliva, gastric juice, and cerebrospinal fluid. Journal of Physiology (London), 1938, 92, 208-218.

Montgomery, M. F. The role of salivary glands in the thirst mechanism. American Journal of Physiology, 1931, 96, 221-227.

Mook, D. G. Oral and postingestinal determinants of the intake of various solutions in rats with esophageal fistulas. Journal of Comparative and Physiological Psychology, 1963, 56, 645-659.

Mook, D. G. Some determinants of preference and aversion in the rat. Annals of the New York Academy of Science, 1969, 157, 1158-1175.

Mook, D. G. and Kozub, F. J. Control of sodium chloride intake in the nondeprived rat. Journal of Comparative and Physiological Psychology, 1968, 66, 105-109.

Nachman, M. and Pfaffmann, C. Gustatory nerve discharge in normal and sodium-deficient rats. Journal of Comparative and Physiological Psychology, 1963, 56, 1107-1011.

Pfaffmann, C. Taste stimulation and preference behavior. In Y. Zotterman (Ed.), Olfaction and Taste. New York: Pergamon Press, 1963.

Pfaffmann, C. Critics comments. In M. R. Kare and O. Maller (Eds.), The Chemical Senses and Nutrition. Baltimore: The Johns Hopkins Press, 1967.

Pfaffmann, C. and Powers, J. B. Partial adaptation of taste. Psychonomic Science, 1964, 1, 41-42.

Richter, C. P. Increased salt appetite in adrenalectomized rats. American Journal of Physiology, 1936, 115, 155-161.

Richter, C. P. Transmission of taste sensations in animals. Transactions of the American Neurological Association, 1939, 65, 49-50.

Richter, C. P. Total self-regulatory functions in animals and human beings. Harvey Lectures, 1942-43, 38, 63-103.

Richter, C. P. and Campbell, K. H. Taste thresholds and taste preferences of rats for five common sugars. Journal of Nutrition, 1940, 20, 31-46.

Richter, C. P. and Eckert, J. F. Mineral metabolism of adrenalectomized rats studied by the appetite method. Endocrinology, 1938, 22, 214-224.

Salmon, T. N. and Blakeslee, A. F. Genetics of sensory thresholds: Variations within single individuals in taste sensitivity in PTC. National Academy of Sciences Proceedings, Washington, D. C., 1935, 21, 78-83.

Schneyer, C. A. and Schneyer, L. H. Electrolyte levels of rat salivary secretions. Proceedings of the Society of Experimental Biology and Medicine, 1959, 101, 568-569.

Schneyer, L. H. and Schneyer, C. A. Inorganic composition of saliva. In C. F. Code (Ed.), Handbook of Physiology, Section 6, Alimentary Canal, Vol. 2, Washington, D. C., American Physiological Society, 1967.

Soulairac, A. The adrenergic and cholinergic control of food and water intake. Annals of the New York Academy of Science, 1969, 157, 934-961.

Soulairac, A. and Soulairac, M. L. Action de l'insuline, de l'atropine, et de l'amphetamine sur le comportement alimentaire du rat. Comptes rendum des seances de la Societe de Biologie, 1959, 153, 1962-1965.

Stellar, E. Hunger in man. American Psychologist, 1967, 22, 105-117.

Stricker, E. M. Influence of saliva on feeding behavior in the rat. Journal of Comparative and Physiological Psychology, 1970, 70, 103-112.

Stricker, E. M. and Wolf, G. Behavioral control of intravascular fluid volume: Thirst and sodium appetite. Annals of the New York Academy of Science, 1969, 157, 553-568.

Teitelbaum, P., Cheng, M. F. and Rozin, P. Development of feeding parallels its recovery after hypothalamic damage. Journal of Comparative and Physiological Psychology, 1969, 67, 430-441

Thaysen, J. H. Effect of sodium restriction on secretion of sodium and potassium in human parotid saliva. Journal of Applied Physiology, 1956, 9, 477-480.

Vance, W. B. Observations on the role of salivary secretions in the regulation of food and fluid intake in the white rat. Psychological Monographs, 1965, 79 (5, Whole No. 598).

Vance, W. B. Oral infusion and taste preference behavior in the white rat. Psychonomic Science, 1970, 18, 133-134.

Wedell, C. H. The taste sensitivity to quinine sulphate. Journal of Comparative and Physiological Psychology, 1936, 21, 223-244.

Yensen, R. Some factors affecting taste sensitivity in man. II: Depletion of body salt. Quarterly Journal of Psychology, 1959, 11, 230-238.

Young, P. T. Studies of food preference, appetite, and dietary habit: IX: Palatability versus appetite as determinants of the critical concentrations of sucrose and sodium chloride. Comparative Psychology Monographs, 1949, 19 (5, Whole No. 102).